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CONTENTS

	Page
LINE-SQUALLS OF MALAYA . . . . . *By* I. E. M. WATTS, M.Sc., Ph.D., A.R.A.N.Z., Malayan Meteorological Service.	1–14
EARLY WESTERN CARTOGRAPHY AND THE ARABIAN PENINSULA . . *By* G. R. TIBBETTS, B.A., University of Malaya.	15–26
ADINANDRA BELUKAR: A Succession of Vegetation from Bare Ground on Singapore Island . . . . . *By* R. E. HOLTTUM, M.A., Sc.D., Professor of Botany in the University of Malaya.	27–32
MIXED GARDEN HORTICULTURE IN JAVA . . . . . *By* Ir. G. J. A. TERRA, lately Professor of Rural Sociology and Ethnology in the University of Indonesia, and Editor of *Landbouw*.	33–43
TRADITION AND PEASANT AGRICULTURE IN MALAYA . . . *By* LIM JOO-JOCK, M.A., University of Cambridge.	44–47
NOTES: THE DEVELOPMENT OF KUALA LUMPUR DISTRICT . . *By* CHONG SECK-CHIM, B.A., Dip. Arts.	48–50
THE PLATEAUX AND FALLS OF EAST SARAWAK . . . *By* F. W. ROE, Ph.D., Director of the Geological Survey Department, British Territories in Borneo.	51
REVIEW: INDIA AND PAKISTAN by O. H. K. Spate . . . *By* E. H. G. DOBBY, Ph.D., Professor of Geography in the University of Malaya.	52

LINE-SQUALLS OF MALAYA

By I. E. M. WATTS

WEATHER ANALYSIS at low latitudes is based on recognition of convergence in the horizontal stream-lines at an upper level of the atmosphere, and such convergence most frequently occurs at the boundary between two air streams of different origin.

The method is subject to two serious defects. In the first place, the position of the rain-belt only approximates to that of the boundary on the 3,000-ft. wind-chart[1], and it is likely that a closer correlation could be found between the rain-area and the boundary at a lower level. Since mountains in equatorial South-East Asia rise to more than 6,000 ft., the air-streams at 3,000 ft. are considerably distorted by orography and it is difficult to determine the boundaries between different streams. Reliable analysis can be made of the wind-field at 7,000 or 10,000 ft., but, as the boundary surface between any two streams has considerable slope[2], the high-level boundary is unrelated to the rain-band.

The second defect in the method of analysis is that upper-wind charts are drawn only at six-hour intervals and surface-weather charts every three hours, and some vigorous storms in regions of high relief have such a short life that their passage may pass unnoticed. This is true in Malaya where the occasional damaging squall is not even reflected in the monthly mean frequency of surface wind-speeds. Some such squalls occur in movements of the boundary separating two air-streams, some are in the onset of the sea-breeze, while many appear to have a different origin.

Consider conditions at Malacca, for example. The following table, showing the percentage frequency of various mean wind strengths, does not reveal the likelihood that winds of damaging force will occur.

TABLE 1. WIND-FORCE AT MALACCA: PERCENTAGE FREQUENCY[3]

Beaufort Force	Calm	1	2	3	4	5	6
Frequency Percentage	1·9	15·4	41·5	30·5	9·6	1·0	0·1

The anemograms, however, show that during the decade 1931–40, there were gusts of 30 m.p.h. or more on 619 days, and of 40 m.p.h. or more on 146 days, while the highest gust was 66 m.p.h. It is also found that most gusts occurred in marked squalls of duration ranging from a few minutes to half an hour, and their distribution is shown in Table 2. This is an analysis of the mean speed and duration of all squalls associated with gusts of 40 m.p.h. or more during the ten years, 1931–40.

1. R. Mather, Unpublished investigation (*Malayan Meteorological Service*, 1952).
2. I. E. M. Watts, "The Equatorial Convergence Lines of the Malayan-East Indies Region". *Memoirs of the Malayan Meteorological Service*, No. 3 (Singapore, 1949), pp. 15-20.
3. Computed from the mean wind over each hour in the decade 1931-40.

TABLE 2. NUMBER OF SQUALLS OF VARIOUS MEAN WIND-SPEEDS AND DURATION ASSOCIATED WITH GUSTS OF 40 M.P.H. OR MORE: MALACCA, 1931–40

Mean Wind Speed in m.p.h.	DURATION OF SQUALL IN MINUTES			
	< 15	15–30	30–60	60–120
19–24	17	27	3	—
25–31	33	53	10	10
32–38	1	4	3	—
Total ...	51	84	16	10

When the squalls occur on the west coast of Malaya during the period from April to November, they are called *Sumatras* and are said to occur simultaneously along a line 200 miles or more in length[1]. The purpose of this study is to examine the character of Malayan squalls, to determine whether they are linear, and finally to decide whether they are related to the movements of air-stream boundaries or are purely local in formation.

Because large changes of wind-direction are common in the slack air-streams of low latitudes, a squall needs defining. The merit attention, the winds initiating the squall must be of greater than normal strength. The autographic records show that the mean wind over Malaya is not usually more than about 18 m.p.h. and that gusts are not consistently over 30 m.p.h., except at hill-stations. Where gusts exceed 30 m.p.h., they are usually associated with marked changes of wind-direction and large, abrupt increases of wind-speed. In this investigation, *significant squalls* will be those in which the wind after a directional change contains gusts of over 30 m.p.h.

On certain parts of the coast most gusts of this speed are accompanied by significant squalls. For instance, at Malacca on 108 occasions during 1936 and 1937 gusts exceeded 30 m.p.h., and on 98 of these a marked squall accompanied them. At hill stations the ratio is not so high because the general flow aloft is stronger than at lower levels.

Isolated cumulonimbus clouds often occur with vigorous, local, non-linear squalls. It is desirable to determine how many of the squalls at an observing station are line-squalls and how many are caused by isolated cumulonimbus. This involves examining the squalls passing each Malayan station on certain days and, after plotting the times of squall-passage (recorded by autographic anemometers), drawing *isochrones* among the stations. If the isochrones of reported squalls appear as straight lines or smooth curves progressing across the country at a speed approximating to the squall-wind, it is reasonable to suppose that they represent the varying positions of one moving line-squall.

Line-squalls will not necessarily be composed of continuous lines of cumulonimbus with equally strong winds at every point along them, because the roughness of the terrain influences both wind and cloud development. Observing stations sheltered from certain directions may not record a significant squall, even though the line-squall is indicated by neighbouring stations. To present a complete picture, some minor wind-changes are plotted. When a line-squall is established from synchronous observations of "significant

1. H. B. F. Moorhead, "Summary of Observations, 1940", *Malayan Meteorological Service* (1941), p. 10.

squalls", the time of any lesser wind-change at another station is plotted, provided the lesser change is apparently not due to a local effect. Thus a weak wind change inland during the afternoon, when convection is at its greatest, is not considered, but if two coastal stations record significant squalls from the sea about midnight, an adjacent weaker wind-change of similar sense might be symptomatic, being contrary to the normal land-breeze regime.

Accompanying the movement of a boundary between two air-streams on the 30th July, 1949, many vigorous squalls were reported, so that it seems likely that the boundary passed as a true line-squall. The squalls of 30th July are plotted in Fig. 1A in the following manner: one wind-arrow at a station shows the direction of the wind *before* the squall, with the speed in m.p.h. noted at the end of it. The other arrow shows the wind-direction immediately *after* the change, the average Beaufort Force within the squall being shown by feathers on the arrow, while the value of the peak gust in m.p.h. is plotted to the left of the station. The local time of the wind-change is given as four figures above the station, and below it are plotted the temperature-drop and the rainfall, each within a certain number of minutes of the time of the squall-passage. Thus, at Port Swettenham on 30th July, 1949, the wind changed at 19.30 hours L.T. from southerly 3 m.p.h. to north-north-westerly, Force 7 with gusts to 39 m.p.h. Temperature fell 8°F. in 30 minutes and there was a fall of 0·06 inches of rain in 10 minutes.

The isochrones appear to show that the passage on this day was in the form of a true line-squall. The first report of it was from Alor Star at 10.25 hours which was not very much later than the normal start of sea-breezes, but gusts of 33 m.p.h. were abnormal for sea-breezes and the rain was exceptionally heavy. Taking also into account that the sea-breeze is usually from a more westerly direction, the Alor Star wind-change appeared to indicate a line-squall, possibly influenced or introduced by the sea-breeze.

Two squalls occurred at Penang, the one at 13.05 and the other at 14.00 hours. The sea-breeze had already developed before 13.05 so that, although winds were stronger after the second change, the first change was probably the more important evidence of a line-squall. On the other hand the line-squall, if it existed, was possibly an uneven broken line, making both changes relevant. This likelihood was supported by a report from H.M.S. *Mendip* (anchored at Penang) that the storm broke at 12.35, when the wind rose to Force 5 within a few minutes.

There was little local indication at Penang of the approaching storm other than thickening cloud to the west. The storm caused considerable damage, many lighters being swept away from merchant ships. The Singapore *Sunday Times* of 31st July gave the following account of the storm: "A gale of almost cyclonic force which hit Penang was followed by heavy seas....., Ground-floor rooms were flooded, and the seas that crashed against the sea-wall catapulted in places to 60 ft. in the air. Streets facing the waterfront were flooded most of the afternoon. The early wind crashed trees across streets all over the island of Penang". Another storm, apparently connected with that at Penang, reached Ipoh later and lasted for about an hour.

The upper winds over the period 29th to 31st July, 1949 are shown with local times in Table 3. At 07.30 on 29th, southerlies (obviously Southern Hemisphere Trades) covered Penang to a depth of 5,000 ft., while at higher levels were the westerlies of the Indian South-West Monsoon. By 31st, north-westerlies had descended to ground-level because the monsoon had been diverted around the northern tip of Sumatra at low levels and was driving southwards the Southern Hemisphere Trades.

TABLE 3: UPPER WINDS, 29TH—31ST JULY, 1949

DATE		JULY 29		JULY 30		JULY 31	
Local Time		07.30	16.30	07.30	16.30	07.30	16.30
PENANG	10,000 ft.	290/16	270/7	..		..	..
	7,000	250/9	310/6	..	Rain	290/24	..
	5,000	170/8	050/6	..		290/31	300/19
	3,000	180/15	180/6	160/14		310/19	300/4
KOTA BHARU	10,000 ft.	280/16	300/17	310/10	..	250/20	290/21
	7,000	240/10	260/10	340/6	..	280/26	280/31
	5,000	230/6	250/5	160/3	..	280/29	270 26
	3,000	270/4	120/2	160/7	270/44	280/16	260/17
PORT SWETTENHAM	10,000 ft.	..	290/3	040/9	030/10	030/13	300/20
	7,000	..	080/4	080/5	050/8	360/10	310/20
	5,000	180/7	110/7	120/8	090/4	350/11	340/20
	3,000	180/15	150/12	130/13	130/14	340/10	330/2

In the expression denoting the wind velocity, the first three figures represent the wind direction in degrees, the rest represent the wind speed in knots. From *Pilot Balloon Data*, Jan-Dec., 1949 (Kuala Lumpur), pp. 56–62.

Surface wind changes at Sitiawan, and both surface and upper-wind changes at Port Swettenham, support the conception of a line-squall moving at about 20 m.p.h. At Kota Bharu there was an abrupt fall of temperature, too large to be ascribed wholly to the light shower, but unfortunately no anemometer was functioning. Changes of upper-wind direction indicated a change of air-stream (Table 3), and the wind of 44 knots at 3,000 ft. suggested the passage of a severe squall.

Inland changes were more difficult to interpret. The squall struck Ipoh from the south-west; the town is well sheltered by hills to the north-west but open to the south-west. Kuala Lipis, which experienced a marked squall, is entirely surrounded by hills, and it is improbable that any reported direction could be representative of the squall.

Further south at Temerloh, Malacca and Mersing, changes were slight and not necessarily connected because the direction of the changes was in accordance with the normal night sequences. Vigorous squalls could not be expected in the south, because a comparison of the morning upper-winds of 31st at Penang and Port Swettenham (Table 3) shows that the squall was probably being retarded as it progressed southwards.

Details in this example show that the changes of wind and weather at stations may offer significant information of the progress of fast-moving air-stream boundaries, but many travel too slowly to be traced by this method. In a region where winds are generally light, the occurrence of an occasional strong wind is readily noticed and the tracing of a line-squall is simplified. At low latitudes, the synoptic method of analysis should be supplemented by a system in which "significant squalls" are reported and plotted to determine linear characteristics, whether or not related to true air-stream boundaries. Stationary local thunderstorms frequently produce squalls and a squall-reporting network must be close before moving line-squalls can be distinguished from isolated convectional storms.

The relative frequency of line-squalls and "significant squalls" at Malayan stations will now be examined for the years 1936 and 1937, when there was a well-distributed network of sixteen recording anemometers in the Peninsula. Every "significant squall" (with gusts of 30 m.p.h.) passing each station was noted. For each day a chart has been plotted (in the manner of Fig. 1) showing the times when squalls passed. Wherever possible, isochrones have been drawn. This method at first appears open to the criticism that, on a single day under some conditions of atmospheric instability, one station might experience several local thunderstorms vigorous enough to indicate significant squalls and render the isochrones unreliable. Such was not the case: two squalls rarely passed a station in one day, so that the question of arbitrarily choosing one did not arise. When any squall passed at a time of day unfavourable for convection, it could be accepted for drawing the isochrones of squalls.

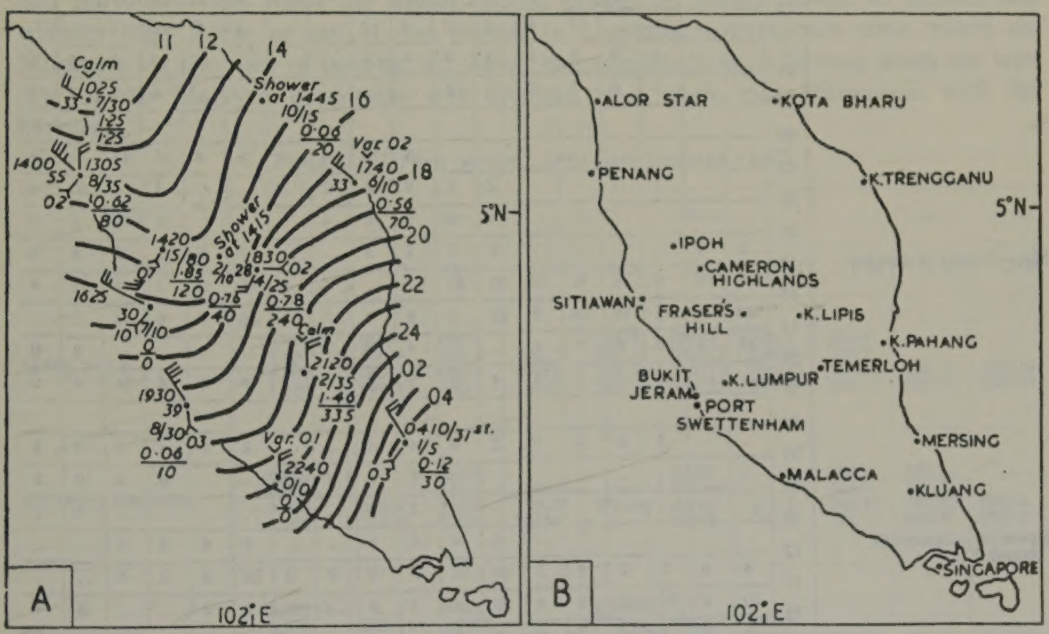

Fig. 1.

A. Squall of 30th July, 1949.

B. Location map of Malaya showing the meteorological stations for which data are plotted on Figs. 1–4.

The meaning of the figures is explained in the text, p. 3.

Table 4 shows the number of "significant squalls" and possible line-squalls passing each station at various hours during the two years 1936–7[1]. Thus, at Kuala Lipis, between 15.00 and 18.00 hours during March and April 1936 and 1937, there were twelve significant squalls and four probable line-squalls.

1. Seasonal frequencies are not comparable as seasons of unequal length have been chosen.

TABLE 4: NUMBER OF SQUALLS AND LINE-SQUALLS IN THE YEARS 1936 AND 1937

Season	Local Time	KOTA BHARU		KUALA PAHANG		KUALA LIPIS		MERSING		BAYAN LEPAS (Penang)		SITIAWAN		KUALA LUMPUR		BUKIT JERAM		MALACCA	
	Hours	Squalls	Line-Squalls	Squalls	Line-Squalls	Squalls	Line-Squalls	Squalls	Line-Squalls	Squalls	Line-Squalls	Squalls	Line-Squalls	Squalls	Line-Squalls	Squalls	Line-Squalls	Squalls	Line-Squalls
March—April (4 months) ..	00	..	..	..	..	..	..	2	0	..	..	..	..	..	..	4	2	2	0
	03	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4	4
	06	..	..	..	..	..	..	4	4	..	..	..	..	..	..	..	..	2	0
	09	..	..	1	0	..	..	4	0	..	..	..	..	2	2	4	4	2	2
	12	4	0	4	2	..	..	6	4	2	0	..	..	8	0	..	..	..	..
	15	..	..	..	..	12	4	2	0	4	2	..	..	4	0	2	2	..	..
	18	..	..	4	0	6	2	2	0	4	4	..	..	..	..	4	2	2	0
	21	..	..	2	0	2	0	4	2	..	..	..	..	..	..	4	2	2	0
	24																		
May—August (8 months) ..	00	..	..	..	..	..	..	..	..	18	10	4	4	8	8	16	14	32	24
	03	..		2	2	..	..	2	2	8	6	2	2	..	..	8	4	20	4
	06	..	..	..	..	..	..	4	2	6	6	4	4	..	..	16	10	6	6
	09	2	2	..	..	..	..	8	2	8	4	..	..	12	6	8	2	8	8
	12	16	10	6	4	10	10	50	20	..	..	4	4	12	2	4	4	6	4
	15	20	8	36	16	14	8	22	8	6	4	2	2	6	0	6	4	..	..
	18	32	2	20	6	10	8	..	..	4	4	..	..	..	..	..	..	2	0
	21	..	..	2	2	2	2	4	0	4	2	..	..	4	2	16	14	4	0
	24																		
September—October (4 months)	00	..	..	2	0	2	0	2	0	4	4	..	..	2	0	4	0	14	8
	03	2	0	..	..	..	..	..	..	8	8	..	..	..	..	4	4	10	2
	06	..	..	..	..	..	..	..	..	2	0	..	..	..	..	..	..	4	2
	09	..	..	..	..	..	..	4	4	6	6	..	..	4	4	2	2	..	..
	12	8	6	2	0	4	2	30	10	2	0	2	0	16	6	4	4	..	..
	15	10	6	26	12	16	6	10	6	2	0	..	..	4	2	..	..	6	4
	18	4	2	2	0	6	0	4	0	..	..	..	..	4	0	4	2	4	0
	21	2	0	4	0	..	..	..	..	..	..	..	0	2	2	8	6	6	2
	24																		
November—February (8 months)	00	..	..	..	..	..	..	4	0	..	..	..	..	..	..	6	4	6	2
	03	..	..	4	2	..	..	4	2	..	..	2	2	..	..	2	2	6	6
	06	..	..	6	0	..	..	6	4	..	..	2	2	..	..	2	0	..	..
	09	2	0	4	4	..	..	8	0	2	2	..	..	2	2	2	2	4	0
	12	4	0	12	0	..	..	10	2	..	..	2	2	14	2	2	0	10	8
	15	..	..	4	2	8	2	8	4	4	2	..	..	10	2	2	0	4	2
	18	..	..	6	0	..	..	8	0	..	..	..	..	..	..	10	0	2	0
	21	2	0	6	0	..	..	6	4	..	..	..	..	..	..	2	0	14	2
	24																		

Squalls in the North-East Monsoon

Table 4 reveals that squalls are not common during the North-East Monsoon (November to February), and that only a very small proportion can be classed as line-squalls. The highest frequency of squalls at this season is in the early afternoon as local convectional storms.

A few weak line-squalls may occur during this Monsoon, as shown in Fig. 2A. They are not easy to identify because the speed of travel in the central section must be about 35 m.p.h. which exceeds that of the observed winds. Wind changes near the west coast on this day may have marked the beginning of the land-breeze, although it is not easy to understand how the squall at Fraser's Hill could have occurred under local influences alone. Low-level wind observations at Kuala Lumpur and Singapore, however, showed a general change from light north-westerlies to moderate or strong northerlies and north-easterlies when the squall passed (Table 5), giving reason to believe that whether truly linear or not, it was related to a moving convergence zone within the Monsoon. At the time of passing, air which had previously been flowing down the west side of the Malayan mountains was diverted to a track more consistent with the Monsoon.

Table 5: Upper Winds, 1st—3rd January, 1937

DATE		JAN. 1			JAN. 2			JAN. 3		
Local Time		07.30	12.30	15.30	07.30	12.30	15.30	07.30	12.30	15.30
ALOR STAR	10,000 ft.	010/5	040/7	..	020/5	090/4	050/5	080/4	..	..
	6,000	350/3	100/5	040/11	060/15	050/15	060/16	050/9	..	..
	3,000	080/11	090/4	040/4	050/18	040/15	060/15	050/23	050/16	050/19
	1,500	060/13	100/2	330/3	060/18	050/21	040/17	060/18	040/12	030/17
KUALA LUMPUR	10,000 ft.	..	280/8	..		030/7	..	270/6	350/11	..
	6,000	..	310/6	290/10	Low	030/10	..	310/8	340/7	..
	3,000	280/7	310/4	270/7	Cloud	350/4	130/3	360/18	040/13	050/4
	1,500	310/7	320/4	250/7		220/6	070/2	360/13	040/5	090/2
SINGAPORE	10,000 ft.	..	240/13	..	270/10	..	..	..	..	..
	6,000	270/14	330/12	..	290/17	300/13	310/10	..	..	..
	3,000	310/11	320/11	270/5	310/9	340/9	340/6	020/24	020/27	010/20
	1,500	350/5	310/9	240/11	360/16	340/9	360/11	020/24	030/31	030/20

In the expression denoting the wind velocity, the first three figures represent the wind direction in degrees, the rest represent the wind speed in knots. From *Pilot Balloon Data*, vol. 2, pt. 1; Jan., 1937 (Kuala Lumpur), pp. 1–9.

Line-Squalls from the South-West with Changes of Air-stream

Another point brought out by Table 4 is that many early morning squalls at Kuala Lumpur, Bukit Jeram and Malacca at the time of the South-West Monsoon (May to August) are line-squalls, as in Fig. 2B. On the 8th June, 1937, a well-defined line-squall crossed West Malaya and moved north-eastwards at about 20 m.p.h. The light low-level winds at Kuala Lumpur and Singapore were southerly to south-westerly before it passed (Table 6), and, because it is unlikely that air with this orientation could have crossed the 8,000-ft. Sumatran mountains, it would appear that the flow consisted of Southern Hemisphere Trades.

TABLE 6: UPPER WINDS, 7TH—9TH JUNE, 1937

DATE		JUNE 7			JUNE 8			JUNE 9		
Local Time		07.30	12.30	15.30	07.30	12.30	15.30	07.30	12.30	15.30
KUALA LUMPUR	10,000 ft.	150/2	..	..	..	270/29	..	280/21	..	..
	6,000	200/9	..	230/18	..	280/27	290/20	330/3	..	..
	3,000	180/15	..	270/5	290/13	320/10	340/9	200/6	160/3	Calm
	1,500	180/11	100/4	180/1	310/12	360/2	360/3	180/9	180/6	130/5
SINGAPORE	10,000 ft.	020/3	360/7	310/8	020/3	..	310/21	320/13	330/10	310/9
	6,000	260/7	250/10	270/19	270/47	270/22	290/21	340/8	260/5	340/6
	3,000	240/7	220/9	250/9	260/30	270/27	270/20	250/10	220/8	270/9
	1,500	200/8	190/9	230/9	250/19	300/5	340/7	180/3	220/5	230/8

In the expression denoting the wind velocity, the first three figures represent the wind direction in degrees, the rest represent the wind speed in knots. From *Pilot Balloon Data*, vol. 2, pt. 6; June, 1937 (Kuala Lumpur). pp. 1–9.

Winds over Singapore changed to strong westerlies after the squall which could have resulted from a change of direction wholly within the Trades, but more likely from South-West Monsoon air which had crossed Sumatra. Changes in the upper winds over Kuala Lumpur supported the analysis that the southerlies of the Trades had been displaced by a new stream from the north-west, possibly a low-level diversion of the monsoon air around the northern tip of Sumatra, similar to the change depicted in Fig. 1. Although the squall introduced little rain or temperature-fall to the north, there was a heavy shower at Singapore.

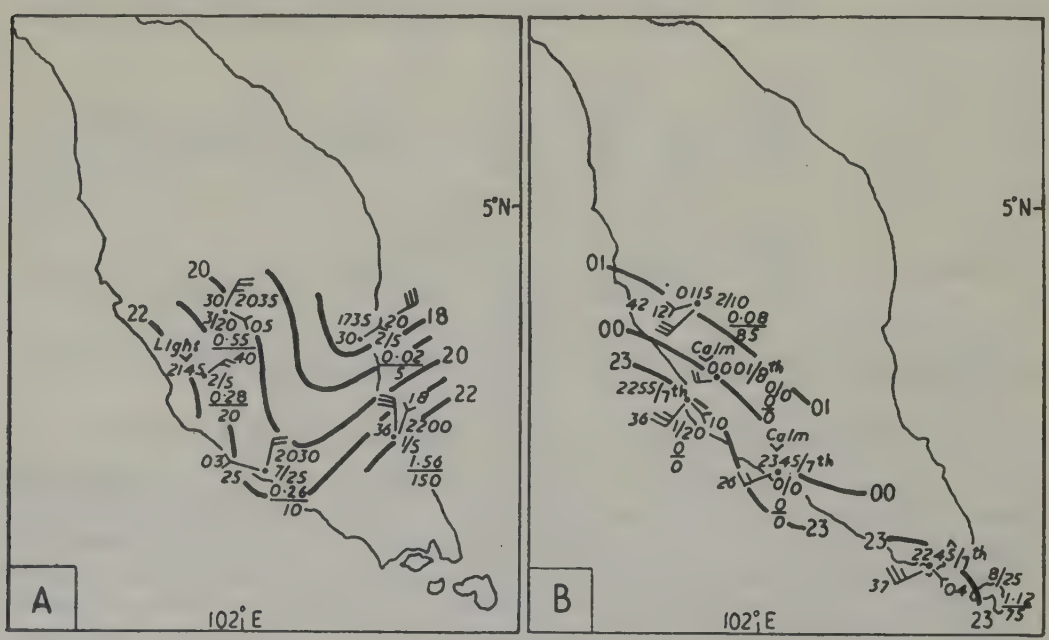

Fig. 2.

A. Squall of 2nd January, 1937. B. Squall of 8th June, 1937.
The meaning of the figures is explained in the text, p. 3.

Most line-squalls from the south-west during the South-West Monsoon have a very different character and negligible changes in wind-structure aloft, as in the example of 1st July, 1936 (Fig. 3A and Table 7).

TABLE 7: UPPER WINDS, 30TH JUNE—2ND JULY, 1936

DATE		JUNE 30			JULY 1			JULY 2		
Local Time		07.30	12.30	15.30	07.30	12.30	15.30	07.30	12 .30	15.30
KUALA LUMPUR	10,000 ft.	..	..	..	..	..	..	280/20	..	..
	6,000	230/10	..	230/10	260/15	260/17	..	260/17	..	330/15
	3,000	180/11	200/9	170/6	210/14	200/9	260/4	220/10	230/3	210/6
	1,500	150/12	190/12	180/5	180/11	160/7	210/4	170/5	180/5	170/4
SINGAPORE	10,000 ft.	..	..	..	..	..	..	310/12	290/19	300/8
	6,000	240/16	..	250/17	250/15	260/15	270/19	260/16	270/13	290/24
	3,000	190/12	170/11	170/13	180/14	170/10	200/9	190/11	240/13	230/16
	1,500	170/15	160/12	160/12	140/17	170/9	180/9	150/11	240/11	210/7

In the expression denoting the wind velocity, the first three figures represent the wind direction in degrees, the rest represent the wind speed in knots. From *Pilot Balloon Data*, vol. 1, pt. 6: June, 1936 (Kuala Lumpur), pp. 4–9 and vol. 1, pt. 7: July, 1936, pp. 4–9.

The winds above Kuala Lumpur and Singapore up to 3,000 ft., both before and after the passage, were undiverted Trades from the south. While the west-south-westerlies at 6,000 ft. may also have been Trades, more probably they were monsoon air which had crossed Sumatra, because directions of flow at 10,000 ft. definitely show that origin. Some convergence might be suspected in the reported veer of wind and slightly increased velocities at 3,000 to 6,000 ft. over Kuala Lumpur, but it is unlikely that this change contributed to the formation of the line-squall; many similar squalls showed no such changes aloft.

Line-squalls of this type, lying wholly within a single air-stream, commonly strike the coast between Port Swettenham and Singapore and they are known locally as *Sumatras*. They consist of a practically continuous line of towering cumulus or cumulonimbus, except occasionally when they may be composed of a few isolated storms along an uncertain line. Sumatras are mainly confined to the period from May to September, and similar line-squalls between March and November may not be so classified, because they accompany a moving air-stream boundary.

On striking the west coast, a well-developed Sumatra is accompanied by gusts to over 50 m.p.h. and by squalls decreasing in violence as the line moves inland at about 30 m.p.h. On most occasions when squalls cross coastal stations there are temperature drops of 5°F. within five minutes or so, decreases not wholly due to cooling by rain because they occur even without precipitation, a condition not found when a line-squall accompanies boundary movement.

Sumatras always occur at night or in the early morning. During 1936–7 the greatest number crossed the west Malayan coast either between 23.00 hours and midnight or between 02.00 and 03.00. The strong winds usually blow for about half an hour, but vary in extreme instances between five minutes and two hours.

Opinions differ about the origin of Sumatras. Some line-squalls seem to originate in convection among the Sumatran ranges before sunset and later travel eastward during the night, for they have been encountered in the evening on the east coast of Sumatra[1]. Most probably line-squalls of this type form in the eastward movement of an airstream boundary.

1. A. Denny, Private correspondence.

Radar observations over the southern Malacca Straits during 1948 showed that, although cumuliform cloud could develop right across the Straits at any time of night, it was mostly confined to the eastern side. Captain A. Denny of Sepang (near Port Dickson in Selangor) describes an occasion when, although the sky was clear to the west at 21.00 hours, a vigorous Sumatra crossed the Malayan coast two hours later. Aircraft reports have shown that thunderstorm activity by night is greatest in the eastern Straits, the region of maximum activity being very close to the Malayan coast a little before sunrise. It is likely, therefore, that most true Sumatras, as distinct from air-stream boundaries, form in the eastern Straits.

What factors contribute to the formation and movement of Sumatras? The air over the region is conditionally unstable and the distribution of temperature with height shows little variation from day to day. Throughout the season of the South-West Monsoon, the westerlies or south-westerlies generally overlie the southerlies of the Trades, and no variations of this structure have been observed on nights when Sumatras have occurred.

Practically every time a Sumatra forms in the Straits, land breezes precede it along the Malayan coast. On other nights when the line-squalls may be ascribed to moving boundaries, the land breezes are not always established before the squall (Figs. 2B and 3A), making it probable that, on nights when Sumatras occur, uplift is initiated by the land breeze undercutting the conditionally unstable air over the Straits, and that radiation from the tops of cumuliform columns further increases the instability and convection. Land breezes from Sumatra may also cause undercutting, but no evidence exists. Supporting the theory that the Malayan land breeze initiates the squall is the fact that clear evenings (which favour nocturnal radiation and early land breezes) precede most Sumatras.

From Fig. 3A and Table 7 it will be seen that the direction in which a Sumatra travels bears no relation to the general wind-structure at low levels, and it can also be shown that the occurrence and movement of these squalls in no way depend on changes in the pressure distribution. Since the direction of movement is the same as the wind direction at 6,000 ft., this wind probably controls it. If the line of cumulonimbus is advanced bodily at 6,000 ft., at lower levels clouds may be constantly dissipating to the west and reforming to the east, a conception justifiable on the grounds that the low-level southerlies are not diverted either before or after.

An alternative theory is that down-draughts from the cumulonimbus pass eastward with the 6,000 ft. current and undercut at ground level to form another series of cumulonimbus columns downwind. These down-currents, of small horizontal extent and short duration, would not necessarily show in upper-wind observations, while the strength of the squall-wind could be accounted for by convergence as the down-draft impinges on the ground.

Sumatras are mostly confined to the coast between Port Swettenham and Singapore, which might be explained by the curvature of the shoreline. Neumann has shown that the degree to which early morning thunder-storms develop over coastal waters depends on the shape of the coast-line[1]. If it is concave, land breezes from its different parts tend to converge towards the centre of the concavity undercutting and uplifting the warmer air off-shore. With a convex coast-line, the land breezes are divergent and the undercutting is less concentrated. From the southernmost tip of Malaya the coast runs nearly straight north-westwards to Bukit Jeram, a section where the Malayan and Sumatran

1. J. Neumann, "Land Breezes and Nocturnal Thunderstorms", *Journal of Meteorology*, Vol. 8, No. 1 (Boston, 1951), p. 60.

coasts are parallel. North of Bukit Jeram, the Malayan coast curves in a great convexity until towards Penang another straight stretch runs to the north-north-west, while the Sumatran coast falls away to the north-west and the Straits widen appreciably.

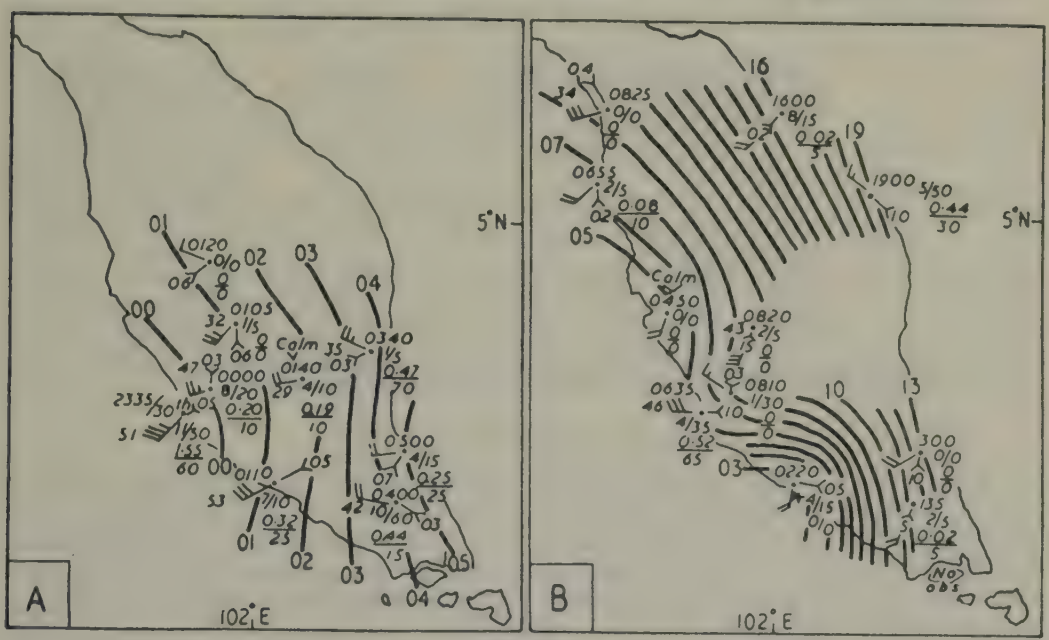

Fig. 3.

A. Squall of 1st July, 1936. B. Squall of 24th July, 1937.
The meaning of the figures is explained in the text, p. 3.

The greatest frequency of Sumatras is in the south where, although the coast is not concave, there is no likelihood of divergence in the land breeze. Divergence might be expected north of Bukit Jeram, where the Straits widen and the general orientation of air-flow up to 3,000 ft. is from the south or south-east. In the central section, where the coast is convex, divergence in the land-breeze would be greatest.

This reasoning is justified by a study of the early morning precipitation along the coast. The frequency of this is influenced by the convective activity brought about by convergence in the land breeze. The highest frequencies of early morning rain from May to September are found at Malacca and Bayan Lepas (Penang), but at Port Swettenham and Sitiawan, in the convex zone, the frequencies are low.

This tendency also shows in the early morning squalls from May to September (Table 4), whose frequencies are greatest at Malacca, negligible at Sitiawan and increase again at Penang. At Sitiawan, on the convex portion of the coastline, every significant squall during the South-West Monsoon is associated with a line-squall, and reference to the original weather charts shows that on most occasions the squalls occurred during the eastward passage of a boundary between two air-streams. The region around Sitiawan is practically free from strong Sumatras.

Sumatras tend to form in the north and south on the same night, as in Fig. 3B and Table 8. These are true Sumatras, with no discernible variation of upper winds as they pass. Small ground changes may occur at Sitiawan when the squalls to the south and to the north are well developed.

TABLE 8: UPPER WINDS, 23RD—25TH JULY, 1937

DATE		JULY 23			JULY 24			JULY 25		
Local Time		07.30	12.30	15.30	07.30	12.30	15.30	07.30	12.30	15.30
PENANG	10,000 ft.	280/26	..	280/23	..	290/16	..	270/17	250/24	230/17
	6,000	260/22	250/17	270/14	..	270/14	..	270/19	230/11	220/9
	3,000	180/15	200/11	170/8	..	120/7	160/7	170/11	190/10	180/9
	1,500	170/15	180/13	190/8	160/15	140/8	200/7	170/12	170/9	190/7
KUALA LUMPUR	10,000 ft.	..	..	..	..	..	..	..	..	..
	6,000	..	..	..	250/13	..	..	240/12	250/16	..
	3,000	180/16	170/13	170/10	200/13	200/13	180/7	250/11	220/9	190/9
	1,500	160/14	170/4	190/4	160/10	170/6	200/5	220/5	190/5	190/8
SINGAPORE	10,000 ft.	240/4	240/6	280/10	..	250/9	230/15	250/6	..	240/11
	6,000	260/7	280/8	250/12	220/17	240/19	230/17	250/11	..	260/12
	3,000	170/18	180/13	180/17	180/20	190/18	200/12	180/15	160/14	190/10
	1,500	160/14	170/9	170/14	160/19	170/15	170/11	160/11	150/6	160/9

In the expression denoting the wind velocity, the first three figures represent the wind direction in degrees, the rest represents the wind speed in knots. From *Pilot Balloon Data*, vol. 2, pt. 7; July, 1937 (Kuala Lumpur), pp. 1–9.

OTHER SQUALLS WITHIN A STREAM

It was shown earlier that the south-eastward advance of an air-stream boundary may be accompanied by a line-squall moving over Malaya. Similar line-squalls occur wholly within the air of the South-West Monsoon when the boundary of the Monsoon is stationary (Fig. 4A). The winds over Penang and Kuala Lumpur on the 15th October, 1937 were north-westerly (Table 9) and in the Indian South-West Monsoon. At Singapore there were westerlies which may have been either monsoon air from across the Sumatran ranges or diverted Southern Hemisphere Trades. The air-stream boundary, therefore, lay either between Kuala Lumpur and Singapore or further to the south.

TABLE 9: UPPER WINDS, 15TH—17TH OCTOBER, 1937

DATE		OCT. 15			OCT. 16			OCT. 17		
Local Time		07.30	12.30	15.30	07.30	12.30	15.30	07.30	12.30	15.30
PENANG	10,000 ft.	..	..	..	..					
	6,000	..	..	..	..			290/29	..	..
	3,000	310/23	300/13	300/25	..			300/23	290/11	..
	1,500	330/9	290/19	310/7	320/16	Rain	Low Cloud	310/12	300/8	290/7
KUALA LUMPUR	10,000 ft.	..	..	..	..	..				
	6,000	..	310/11	..	260/18	..			..	
	3,000	330/20	310/11	310/20	300/11	..			..	
	1,500	340/12	300/15	320/16	320/9	330/23	Rain	Mist	310/4	Rain
SINGAPORE	10,000 ft.	310/22	..	300/20	270/19	280/17	270/16	290/19	300/30	270/22
	6,000	310/12	..	290/5	290/11	270/15	260/17	290/14	290/18	290/22
	3,000	250/11	..	250/13	250/11	260/28	260/28	250/23	280/15	250/20
	1,500	250/8	250/10	240/13	250/10	260/22	270/9	250/17	260/11	270/20

In the expression denoting the wind velocity, the first three figures represent the wind direction in degrees, the rest represent the wind speed in knots. From *Pilot Balloon Data*, vol. 2, pt. 10; Oct., 1937 (Kuala Lumpur), pp. 1–9.

The squall arrived on the coast in the early morning, probably initiated by a Sumatra, possibly by a disturbance which had travelled undetected over the Bay of Bengal. The evidence of ground and upper-winds (Fig. 4A and Table 9) shows that the squall is unlikely to have reached Singapore. It is difficult to associate the vigorous squall at Mersing with the moving line-squall. A feature of this kind occurs regularly: when a

line-squall appears within an air-stream and near the boundary, another squall or line-squall is often induced within the neighbouring stream so that the two, although converging on the boundary, have a velocity component along its length.

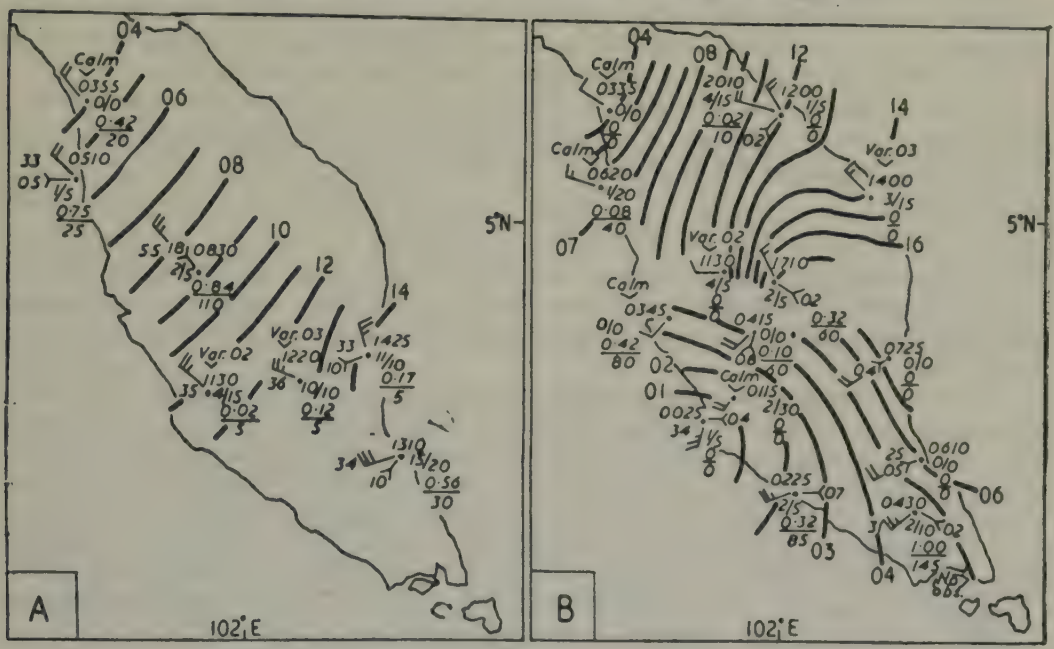

Fig. 4.

A. Squall of 16th October, 1937. B. Squall of 10th July, 1937.
The meaning of the figures is explained in the text, p. 3.

On 9th July, 1937 (Table 10) the low-level flow at Penang showed that southerlies or south-easterlies, apparently Trades, covered Penang and Kuala Lumpur. Winds were more south-westerly at Singapore but, assuming that there were Trades in the north, the south-westerlies in the south were also diverted Trades.

TABLE 10: UPPER WINDS, 9TH—11TH JULY, 1937

DATE		JULY 9			JULY 10			JULY 11		
Local Time		07.30	12.30	15.30	07.30	12.30	15.30	07.30	12.30	15.30
PENANG	10,000 ft.	200/5	120/4	180/1		260/6	..	320/16	300/24	290/16
	6,000	270/9	260/6	190/5		230/5	290/10	300/14	300/15	300/12
	3,000	190/5	120/3	180/3		060/6	350/9	330/6	260/1	350/5
	1,500	160/16	160/5	210/8	Rain	010/5	320/6	030/10	180/2	270/1
KUALA LUMPUR	10,000 ft.	360/2	..	..	..	..	..	..	..	..
	6,000	310/10	..	050/8	..	..	..	350/10	..	..
	3,000	100/3	170/5	170/5	240/6	100/2	170/9	350/5	310/6	..
	1,500	110/3	160/3	190/6	170/6	170/2	180/7	130/4	290/5	290/9
SINGAPORE	10,000 ft.	280/7	280/12	270/11		250/23	230/9	280/4	300/6	290/9
	6,000	270/17	290/12	250/9		230/22	250/8	250/6	270/6	310/9
	3,000	260/13	240/13	200/7		210/13	200/7	190/9	250/3	310/12
	1,500	230/10	210/11	190/10	Low Cloud	180/13	120/9	180/3	180/9	310/10

In the expression denoting the wind velocity, the first three figures represent the wind direction in degrees, the rest represent the wind speed in knots. From *Pilot Balloon Data*, vol. 2, pt. 7; July, 1937 (Kuala Lumpur), pp. 1–9.

At Penang, the upper-level change to north-westerlies during the morning of the 10th represented the advance of an air-stream boundary which did not reach Kuala Lumpur and Singapore until the 11th. While the boundary was advancing in the north a separate squall, wholly within the Trades, crossed southern Malaya (Fig. 4B). In this example, it might be considered that the more southerly squall was partly due to a Sumatra, but dual squalls of this nature may occur at any time of the day.

When a squall occurs within an air-stream, or when one stream advances and displaces the air-stream boundary, a secondary line-squall is probably induced within the other stream so that the two travel parallel to the boundary.

The Local Problem

Line-squalls over Malaya conform to patterns: some are in movements of the air-stream boundaries and relate to the weather-chart, while others consist of disturbances moving within a stream, not readily discernible on the chart and often originating from local causes.

Because relief influences the form and intensity of disturbances, the use of the synoptic chart in detailed study of the daily weather must be supplemented by a consideration of local developments. These small-scale changes may be evident in observations made at a station at regular intervals but, because most squalls last only about half an hour, each station should report the passing of every "significant squall".

The problems of forecasting line-squalls are not peculiar to South-East Asia, for they occur in many parts of the equatorial belt. About one-fifth of the equatorial region is occupied by land or by islands adequate for the creation of a reasonable network of stations reporting at short intervals. Over the remaining four-fifths islands are very scattered, so that not only is the synoptic reporting network unsatisfactorily spaced, but it is impossible to supplement it with a squall-reporting service.

EARLY WESTERN CARTOGRAPHY AND THE ARABIAN PENINSULA

By G. R. TIBBETTS

IT WAS not until the thirteenth century that Arabia began to appear on Western maps as a geographical entity. Before that time it was but a curiosity at the southern end of the Holy Land, and medieval religious maps, if they mark it at all, give no more detail than a pictorial representation of Mount Sinai, occasionally adding Mecca as the religious centre of the Saracens. The Greeks had known more about Arabia, but with the single exception of Ptolemy, I have not dealt with them here. Ptolemy's influence on Renaissance cartography makes it necessary to mention him fully, but rather as a Renaissance geographer than as a Greek[1].

The Arabian Peninsula never held any great attraction for early travellers from the West, who usually set out with some aim in view, and with few exceptions travelled for political, religious or commercial reasons. Politically, Arabia was unimportant. The marauding Bedouin of the interior, occupied as they were with intertribal feuds, presented no great threat to the outside world. Neither had any European potentate a strong desire to acquire such a barren and unprofitable land. Religious missionaries had other more rewarding places to visit than the very cradle of Islam, which was vitually forbidden to all but Muslims. Commercially, too, Arabia was of little interest. Until the discovery of oil, the Peninsula produced nothing of great enough value to attract the attention of Western merchants, except the coffee and spices of the South. Before the rise of the Ottoman Empire the trade routes to Europe from the East had run north of the Peninsula from the Persian Gulf to the Mediterranean, while trade through the Red Sea had been in the hands of the Mamluke kingdom of Egypt.

Among European travellers in the Middle Ages, Marco Polo was the first to make mention of the Peninsula. In his book he gives a description of the island of Socotra; then, after describing parts of Africa he comes back to Aden, *Escier, Dufar* and *Calatu,* before continuing the relation of his stay in *Hormuz* and his return home. It is most likely that Marco Polo did not visit these places, that the whole trip in this direction as far as Madagascar is fictitious, and that he only obtained his information concerning them at second-hand during his stay in *Hormuz.* He leads us to suppose that the south coast of Arabia runs north-west from Aden to *Hormuz,* but nevertheless, his brief accounts do show a fairly accurate knowledge of the inhabitants of these regions.

Few European travellers ventured into the Peninsula itself, and fewer left accounts of their travels, while none took measurements. Their travels are little more than the record of the number of days taken to journey from one place to the next. Much of their information about the Peninsula was obtained at second-hand from the tales of Arab tribesmen, whose journeys from place to place, measured by camel marches, must have been the basis for the positions of many inland towns. The same thing happened in every century; Ptolemy must have used this method, Ibn Battuta and Doughty both admit that they worked in this way. The errors of such a method are very great, for a town is

1. See p. 17 et seq.

placed at an uncertain distance and in a vague direction. Nothing is known of the meanderings of the route or the circumventions of mountains, sands or lava tracts, whilst the physical capacities of camels are not taken into account.

Ludovico de Varthema, the Italian, at the beginning of the sixteenth century, was the first of these travellers. He started from Damascus and travelled down the pilgrim route to Medina and Mecca, and then took ship at Jidda for Aden, whence he was forcibly taken to Rada'. Later he covered a large part of the Yemen, before sailing to India from Aden. His account was published in Rome in 1510.

In 1507 the Portuguese landed in Oman, and they remained in occupation of parts of the coast until 1650, during which period their fleets were much in evidence round the Arabian coast. The Portuguese, however, except for a few renegades or captives, never penetrated into the interior, so that their accounts, such as the commentaries of d'Albuquerque, give only the vaguest picture of inland Arabia.

At the end of the century Jan Huyghen van Linschoten sailed round the southern shores of Asia. He was followed a few years later (1609) by a British ship, the *Ascension*, a member of which, John Jourdain, journeyed inland from Aden to San'a, returning to his ship at Mocha. His journal containing his observations on the journey was not published until 1905. Two other Englishmen actually penetrated the interior during this period. The account of the first, Captain Middleton, who was forcibly taken into San'a from Mocha, adds little to that of Jourdain. The other, Joseph Pitts of Exeter, made a slave by Muslims as a youth and forced to adopt their religion, tells us much when later he accompanied his master on the pilgrimage. The French commercial expedition to Yemen in 1710 gave rise to a map which will be discussed later. Other travellers such as Thévenot, Teixeira, Della Valle and Tavernier touched the northern fringe of Arabia but have very little to say about the Peninsula itself.

The total information extracted by the cartographer from these travels was small. Marco Polo's book was at first little known, although it later became one of the most popular travel works of the Middle Ages. Some eighty manuscripts exist and it was printed in many editions, the first being in 1477. But in spite of this it did not exercise a great deal of influence on the development of cartography. The Laurentian World Map[1] of 1351 gives a few places mentioned in Polo's travels; so does the Catalan World Map of 1375 and Fra Mauro's planisphere, but it was not until Gastaldi produced his map of Asia in 1561 that any cartographer really used Polo as a source.

The Linschoten travels and the French expedition of 1710 both led to the production of contemporary maps, but these were taken primarily from already existing maps, and, in the second example the chart of the route was made to fit into a very inaccurate map. The influence of other travels can be noticed occasionally. The maps of Van der Aa in 1707, designed to show the routes of travellers, were of course compiled long after most of the voyages had taken place. They were extremely badly drawn, far below the standard of contemporary cartography, and had no effect on future maps.

Muslim travellers had described the Peninsula in some detail. Gazetteers, itineraries and more scientific geographical treatises written in Arabic were numerous, as well as collections of maps. The Arab navigators who had for centuries sailed the Indian Ocean produced their own detailed charts of that Ocean, and it was an Arab pilot, possessing both charts and compass who first guided Vasco da Gama to India from Malindi on the coast of Africa. The Muslim geographers, however, played little direct part in the production of Western maps. Idrisi, the best known of them, had been Court Geographer

1. Properly called the *Portolano Laurenziano-Gaddiano*.

to the Norman king of Sicily, Roger II. But except that the world map of Marino Sanuto (1321), and the Este map of 1450[1], showed a vague understanding of Idrisi's cosmographical system, his work was unknown to Western cartographers until it was printed in Italy in 1592. This version was translated into Latin and published in Paris in 1619, under the title of *Geographia Nubiensis*. The next work of the Arab geographers to become known in the West was Abu'l Feda's description of Arabia, which was first published in Volume 3 of John Hudson's *Geographicae Veteris Scriptores Graeci Minores* in 1712. This translation was, however, unknown to La Roque when he made the French translation in an appendix to the work of D'Arvieux entitled *Travels in Arabia the Desert* (1718). The former was decidedly the superior work. It was accompanied by the Arabic text, and included the tables of longitude and latitude of Ulubeg and Nassir Eddin as given by Abu'l Feda. Except for short extracts translated by D'Herbelot in his *Bibliothèque Orientale* (1697), the other Muslim geographers remained unknown to the West, even in translation, until the nineteenth century.

Perhaps the earliest surviving map produced by Western cartographers which gives contemporary detail of the Arabian Peninsula, is the Laurentian World Map mentioned above. This marks five towns on the south and east coasts of Arabia. The earlier medieval maps, if they marked Arabia at all, had only mentioned biblical names and occasionally added Mecca, but the portolan charts, from which the Laurentian world map is a compilation, were surprisingly accurate and detailed. Their topographical content, although limited to coastal features, is of great importance. Many of the Arabian place-names can be recognized easily on a modern map. They were supplemented by *roteiros,* or *rutters* as they were called in England, which were descriptions of the coasts and harbours. Several of these dealing with the Indian Ocean have survived, for example, the works of João de Lisbõa and André Pires. The roteiro of João de Castro is probably the earliest Western work on the Red Sea. Although the author sailed up and down the African coast, he also mentioned a few of the places on the other side of this sea.

The first printed map to show "modern" detail of the Arabian Peninsula,[2] the *Tabula Moderna Indiae* of Waldseemüller, from the Ptolemy edition of 1513, is drawn completely from contemporary portolan material, but being one of the first attempts to reproduce maps by wood cut, it is not a good example of their accuracy. It is a mystery why such a large number of the seventeenth-century cartographers clung to Gastaldi's map of Asia of 1561 for their coastal detail, when they could have utilized the information given on more up-to-date sea charts. Langren's map of 1596, illustrating Linschoten's travels, however, is an example of a map which, although based on Gastaldi for the interior, did use portolan charts for coastal detail. This can be seen by comparing this map with Gastaldi's of 1561 and with the chart reproduced as Plate XVIII in Caraci's *Tabulae Geographicae Vestustiores.*

These early advances in the development of medieval cartography were retarded by the resurrection of the Greek astronomer, Ptolemy. The flow of Byzantine manuscripts to the West during the fifteenth century brought with it several examples of his work and maps, thereby starting a revival in the study of scientific geography. It was natural that the early printers, whose heads were turned by anything Greek, should notice Ptolemy and his maps. The first edition of his work was published in the Latin translation of

1. From the R. Biblioteca Estense at Modena.

2. "Modern" is the term used to distinguish maps included in editions of Ptolemy but showing contemporary features, as opposed to purely Ptolemaic maps.

J. Angelius in 1475, and a corrected edition was printed in Bologna in 1477[1], accompanied by twenty-six engraved maps. These editions were successful and the *Geography* ran into many editions, becoming immensely popular during the sixteenth century, and was still used as an historical atlas even after modern atlases had come into their own.

Ptolemy has two maps which cover Arabia: *Quarta Asiae Tabula,* covering *Arabia Petraea* and *Deserta* with Palestine, Mesopotamia and Syria; and *Sexta Asiae Tabula* covering *Arabia Felix*. These were the first detailed (or large scale) maps of Arabia to be published and appeared for the first time in printed form in the edition of Ptolemy's *Geography* published by Angelius Vadius in Bologna in 1477. Several manuscripts, however, dating from an earlier period are extant, such as the Ebner Manuscript in the New York Public Library[2]. Ptolemy started, like the other Greeks, by exaggerating the longitudinal measurement of Eurasia, and because of this, much of the lesser known part of the world was extended by him in an east-west direction. Arabia suffers because of this, for Ptolemy allowed too much space between the African coast of the Red Sea and Persia. In the north of the Peninsula, where traders had a good knowledge of distances, Ptolemy was able to plot the land mass with reasonable accuracy, but he had to leave a wide stretch of water for the Persian Gulf. On the other hand, in the south he knew that the entrances to the Persian Gulf and the Red Sea were narrow; therefore, he had to exaggerate the width of the little known land-mass of Arabia. This is important, for the resulting shape of the Peninsula influenced future maps of Arabia for some time. This over-estimate of the dimensions of Eurasia can be seen in maps of Asia for another two hundred years. It was first corrected by De L'Isle in his maps of the world and the four continents published in 1700[3].

The division of Arabia into *Petraea, Deserta* and *Felix* which occurs in Ptolemy was the general division in classical times. It is in a sense a natural division and was more or less the political division in the days of Rome and the Nabatean kingdom. But the boundaries of Ptolemy persisted in nearly all maps of the Peninsula until the time of D'Anville (1750). A few enterprising cartographers increased the size of the desert at the expense of *Arabia Felix*, but the more orthodox caused the boundary to revert to its old position. D'Anville and later geographers used the three terms as regional names even until quite recent times.

The topographical content of Ptolemy's map has been the subject of much discussion amongst scholars. He has been accused by some of adding fictitious names in the interior, but Alois Sprenger, in his *Alte Geographie Arabiens,* by producing modern details to correspond with the Greek toponomy, has proved that much of Ptolemy's information is authentic. Some vagueness is only to be expected since he must have relied completely on the accounts of the natives. A full discussion of Ptolemy's maps of Arabia can be found in Sprenger's book, which was published in Bern in 1875. More recent work can be found in the appendix to Musil's *Arabia Deserta*, but this only deals with the northern desert[4].

1. The date assigned to this edition by Sighinolfi and Lynam, *The first engraved atlas of the world, the Cosmographia of Claudius Ptolemæus, Bologna 1477* (George H. Beans Library, Jenkintown; 1941).

2. Reproduced in E. L. Stevenson, *Geography of Claudius Ptolemy* (New York, 1932).

3. The length of the Mediterranean was also over-estimated, which had the effect of exaggerating Arabian longitudes. Gastaldi and Mercator used a standard meridian about 23° West of Greenwich, and their meridian of 70° East passed somewhere in the region of Jerusalem, Damascus or the Palestinian coast. Blaeu normally used the longitude of Tenerife, 16° West of Greenwich, as his prime meridian, which brought his 70° some distance East of Aleppo. A French royal decree of 1634 constrained all French cartographers to use the Ile de Fer as a standard (assumed by De L'Isle to be 20° West of Paris). Therefore, 70° East passes through Medina and Damascus in the maps of Sanson and his successors. De L'Isle's new estimate for the longitudinal length of Eurasia reduced the longitude of Mecca to 58° East.

4. South Arabia has recently been re-examined in "Beiträge zur historischen Geographie des vorislamischen Südarabien von H. von Wissmann und M. Höfner", *Abhandlungen der geistes- und sozialwissenschaftlichen Klasse*, 1952, Nr. 4. *Akademie der Wissenschaften und der Literatur in Mainz.*

Fig. 1. Part of Gastaldi's map of Arabia, 1561.
(Reproduced by permission of the Trustees of the British Museum).

Fig. 2. Part of D'Anville's map of Arabia, 1751.
(Reproduced by courtesy of the Syndics of the University Library, Cambridge).

Ptolemy's mountain system was very sketchy and was soon superseded in "modern" maps by Gastaldi's complicated system of ranges. Gastaldi, however, took over Ptolemy's river system and adopted it for use on his own map. This included a large lake, *Stag Lago* in Gastaldi's 1548 map and *Stygis Fons* in Ptolemy, which may have been the waters of Yemen which flow east into the desert, or the reservoir of Marib. In the printed maps this becomes a large lake, which is taken over by Gastaldi who, in 1561, inserts another lake for the reservoir of Marib. The ghost of *Stag Lago* lingers on, slowly approaching the sea in the maps of the next century. It then becomes a bay which gets smaller until it finally disappears. The various editions of Ptolemy agree in most details with each other, and with the manuscripts of the fifteenth century, but some, through lack of space or for the sake of clarity, omit certain details, some add a few extra streams, and some divide the peninsula into regions with dotted lines.

The first printed "modern" map of the whole of the Peninsula was produced by Giacomo di Gastaldi to accompany the Venetian edition of Ptolemy's *Geography* of 1548. This is a small map with little detail. The names of most towns are unrecognizable, and few can be identified. It is doubtful whether Varthema's book, which was published in 1510, was used when compiling this map, for the detail in these two works does not correspond. *Taiṃa* appears in the map, but is not mentioned in Varthema; Gastaldi has *Lamech* for Mecca, *Sama* for San'a, but *Reama* (Yarim) is used by both, although Gastaldi places it roughly in the position of Yamama. *Gezen* (Qizan), mentioned in Varthema, appears in the 1548 map, but not in that of 1561. The only regional name is *Mamonta*, which must be a contraction of Ptolemy's *Climax Mons*, or perhaps *Chatramonitae*. Very different was Gastaldi's attempt in 1561 (Fig. 1), when he published the second part of his map of Asia, *Il disegna della seconda parte dell'Asia*. In this large-scale map there appeared for the first time much material which was to recur in all Western maps for the next century and a half. He must have discovered much information concerning the Peninsula after he had produced his map in 1548.

Between 1548 and 1561, there had appeared the celebrated work *Delle Navigationi e Viaggi*, a collection of voyages edited by Gian Battista Ramusio. This work contained both the accounts of Varthema and Marco Polo. Nordenskjöld compares the nomenclature of Gastaldi with the Ramusio edition of Marco Polo, and comes to the conclusion that Gastaldi's map of Asia was based on the latter work. It is also obvious that, if Gastaldi used Ramusio, he must have had the Ramusio text of Varthema, which added to his information about the Arabian Peninsula. Ramusio also gives tables of longitudes and latitudes taken from a manuscript of Abu'l Feda, but the positions of places on the map do not correspond at all with the positions demanded by the tables. The only other comprehensive set of tables of latitudes and longitudes in existence was that of Ptolemy, and perhaps Gastaldi's bad shape for the peninsula was due to an attempt to adopt these tables to his modern nomenclature. The names along the coast and on the islands must have been taken from portolan charts and the discoveries of the Portuguese and Spaniards during the early part of the sixteenth century. The remainder of his information must have come from other sources still unknown. But, as a friend of Ramusio and Lafreri, it is possible that Gastaldi had access to the accumulated archives of Venice and Rome, and, as the *Terza Parte* of Asia is dedicated to Marco Fuchero, it is probable that Gastaldi had access also to the valuable archives of that family.

Gastaldi's detail is thick around the coast and thins out towards the interior, perhaps showing that most of his informants were sailors who had obtained information from their ports of call. The centre of the map contains nothing but a series of deserts named after corresponding places on the coast. This central area of desert was filled up

gradually by Gastaldi's successors who broadened the coastal strips until they met in the centre. This process continued until the centre was once more cleared by De l'Isle in 1700. The coastal areas of Gastaldi were divided off according to the local regions or political divisions. The latter may have been tribal areas or the territories of local dynasties, thus accounting for such names as *Alibinali* and *Amansirifdin.* Gastaldi's treatment of the Hejaz is rather more detailed and there is much more in his map than in Varthema's account. Among the important towns which have not appeared before on a printed map, Gastaldi has marked *Medinatanalbi, Ianbut* (Yanbu) *Ziden* (Jidda), *Eltaif* and *Hali. Medinatal Nabi* is the form used by Varthema. On the second plate of Ortelius's map of Asia, engraved for the 1579 *Theatrum Orbis Terrarum* it has been made into two towns, *Medina* and *Talnabi,* and so it appears in Nansen's *Compendium Cosmographicum* of 1646.

The physical features of Gastaldi's map are taken from Ptolemy. Gastaldi only names mountains which appear in Ptolemaic maps, but his mountain system is completely different, since he invents ranges to divide each region from the next. The rivers too are Ptolemaic with a few additions. Ptolemy's *Baetius* becomes *Eda*; the *Lar* becomes the *Om*, the *Prion* the *Prim*; the fate of *Stygis Fons* has already been mentioned. The only other river named, *Cozara*, flows into the neighbourhood of what is now Kuwait. This could be the Shaib al-Qusair which flows through al-Qusair into the sands near Basra. The Marib reservoir, well known from the references to it in classical writers, is fitted by Gastaldi into the centre of the southern strip. A large lake occurs together with the town of Marib on the east. It is supplied with water from a river which flows from the north, past Najran. This easterly position for Najran and Marib is maintained in all later maps for a considerable period, even after the towns have been located more correctly. In fact several maps are found with Najran shown twice, but usually with different spellings. This duplication of material is common until the time of De L'Isle. Whenever a cartographer copied from different sources he was liable to insert the same town in two different places. Thus Gastaldi has two towns for Yanbu (*Ianbut* and *Ianbog*)[1], and two Hadramauts (*Castermut Mons* and *Cazirmut.*). Mercator, in his map of the world, has two Hijaz deserts (*Egeza and Agiaz*), and there are numerous other examples.

Gastaldi's map was copied by nearly all cartographers for many years to come. Ortelius, in his map of Asia in 1567, quotes him as a source, and in the map of Turkey in his *Theatrum* of 1570, Ortelius has taken Gastaldi's material but omitted all the mountain ranges except those actually named. Mercator, too, follows him closely but has simplified the mountain system. In his map of the world, 1569, he makes Gastaldi's Eastern Range the main mountain chain of the Peninsula, a mistake copied by several cartographers and which partly influenced Sanson. Moreover, on Mercator's map towns are found in the *deserto* areas, which were left blank by Gastaldi. The younger Mercator, in his map of Asia in the *Atlas* of 1595, and Langren in 1596, both use the topographical arrangement of the 1569 world map.

The Langren map was produced to accompany the edition of Linschoten's *Navigatio ac Itinerarium* in 1596, and was copied in several other works. The surprising fact about the representation of the Peninsula is the close resemblance of the outline to that of a modern map when compared with other engraved maps of the time. There is a vague suggestion of the Qatar Peninsula, which is not seen again until the nineteenth century, but Sinai is not shown as a peninsula. The map is primarily a sea chart, coastal details

1. Gastaldi may also have been influenced by the knowledge that Yanbu has always been counted as two places, the village, some distance inland, and the port.

are represented with reasonable accuracy, and many of the places can be found on a modern map. The interior has been taken from Gastaldi by way of Mercator, whilst an attempt has been made to link up Gastaldi's river system with the inlets marked on the charts of the time. Copies of the map continued to be made for another fifty years, both for editions of Linschoten's work and for use in the small atlases of Langenes, Bertius and Visscher.

Willem Janszoon Blaeu published a large map of Asia in 1608, a copy of which belongs to the *Royal Geographical Society*. In this the topographical detail of the Peninsula is brought up to date. Arabia is again based on the information supplied by Gastaldi but a better shape has been obtained by comparing it with charts. There is no coherent mountain system, just vague molehills in the centre. Towns are packed tightly into the south-west corner. This map became the basis for the Asia map which appeared in Hondius's edition of Mercator's *Atlas* in 1623, as well as for the map of Turkey from Blaeu's *Atlas* of 1635 and that of Arabia from the 1662 edition of the same work. Its influence can also be seen in the maps of Sanson. There is also a world map produced by Blaeu in 1605, of which a unique copy is owned by the *Hispanic Society of America*. Very little of the Arabian Peninsula has survived but that part which still exists corresponds closely with the 1608 map of Asia.

Blaeu's map of Arabia did not appear in his *Atlas* until the edition of 1662. It was probably published earlier, before Sanson's maps of 1652 and 1654, for Blaeu had no knowledge of these when he drew it, or if he had, he did not include any of Sanson's emendations. Based on his earlier maps, this one lags a long way behind contemporary cartography. The route from Mocha to San'a is very detailed, and so is the south coast as far as *Dolfar* (Dhufar). For the latter, a sea chart has obviously been consulted. The Mocha-San'a route agrees with that of Middleton, but was probably taken from the account of Pieter van den Broecke[1], the Dutch traveller who followed the same route in 1616. Blaeu's boundaries are his attempt to show contemporary kingdoms. *Zibit, Aden, Herit,* and *Fartach* are all kingdoms according to his text, but the rest of the Peninsula must have been too difficult for him to attempt. His extra information caused a lot of duplication. For instance, Ta'izz appears in Gastaldi and Blaeu's Turkey as *Taesa,* near the river, and close to *Elfagui* (Bait al-Faqih). The new Ta'izz is called *Tayesse* and appears south-east of Zibith. Another example is Yarim; Varthema's *Reama* is *Rehama* in Blaeu's map, but the new *Ierreme* appears some distance to the west. *Hadermuidt* is added inland, which makes a total of three Hadramauts if Gastaldi's *Cazirmut* and *Castermut Mons* are included.

The first real improvements came with Nicolas Sanson, the famous French cartographer, who published a map of Arabia, dated 1652. In this map he removed from the south-west corner the lake which was a survival of Ptolemy's *Styx,* but Marib and its lake remain half-way along the south coast. Sanson for the first time adopts the idea of a single mountain range down the Peninsula. In order to do this he moves Mercator's main range, which was on the east, to the middle of the Peninsula. Detail of the Hijaz is then spread across the gap to fill out the western side of this range, and east coast information is likewise extended towards the range. Thus Sanson omits altogether the desert area placed down the centre by Gastaldi, for which he had no information. Important places which now appear are *Tabuc, Batn Nackel, Abadan* and *Hagiar;* also *Zibit fluvius* and *Laakic fluvius* (al-'Aqiq), the river of Medina. These seem to show that Sanson had made use of the *Geographia Nubiensis*. Tribal areas appear under the general terms

1. *Korte Historiael ende Journaelsche Aenteyckeninghe van al 'tgheen merckwaerdich voorgevallen is, in de langhduerighe Reysen, soo nae Cabo Verde, Angola, & als insonderheydt van Oost-Indien* [etc.] (Haarlem, 1634).

Beduins and *Bengebres* (The *Benjabar* of d'Albuquerque, perhaps a tribe of the Oman hinterland or a native dynasty of the time of d'Albuquerque). Sanson's errors were the placing of *Iaman* over Hijaz instead of further south, inserting *Tima* (Taima) south of Yamama, and turning the Wadi Najran round to flow into the Red Sea, because of his more accurate placing of the town of *Najran.*

Sanson produced a new and larger map of the Peninsula in 1654, which was in the main a copy of the first. This restored the term *Hagias* (Hijaz), although *Iaman* was still placed over this area. It also changed the border of Bahrain, extending this province as far as the boundary of *Arabia Deserta.*

Sanson's material was used by several cartographers in the next few years, the most important of whom was Frederick de Witt. His map of South-Western Asia, entitled *Nova Persiae, Armeniae, Natoliae et Arabiae Descriptio,* had perhaps the longest life of any of the maps of this area, appearing in many of the important atlases produced in Amsterdam for a period of over eighty years. De Witt's map of Asia which appeared in his atlas is also taken from Sanson, but his map of the Turkish Empire is based on Janson and Blaeu.

Sanson's son, Guillaume, reproduced the maps of his father with corrections and additions. In his map of Turkey he adds the boundary of the *Estats du Cherif de la Mecque,* covering the highlands of the Hijaz as far south as Najran, and the boundary of the *Beglerbeglic de Iemen ou Aden,* including the seaports from Jidda southwards and along the coast to Dhufar. In calling this *Iemen,* he corrects his father's error of placing Yemen in the Hijaz. In his map of Asia, published in 1669, the younger Sanson adopted a more complex system of boundaries. The districts formed by these seem to represent the regional names of the manuscript maps of Idrisi. The inclusion of *Seger,* which is *Shihr* misread in the Arabic, shows the use of the 1619 translation of Idrisi's *Geographia Nubiensis,* where this error first occurred. Shihr in the earlier maps appears in the form of *Xaer* or *Xael,* which form reappears in the map of the younger Visscher.

These maps of Guillaume Sanson were followed by most of the cartographers of the time, and were later adopted by Ibrahim Mutefarriqa, when printing the first edition of Katib Chelebi's *Jihan-numa* in 1728. De Witt, whose map of Asia had been published earlier, now added these boundaries to his plate, together with those regional names (*Seger* and *Mecca*) which were not there already. It is interesting to note that those cartographers who used Guillaume Sanson's boundaries, used those of his Asia map of 1669 only for their own maps of Asia. For their maps of the Turkish Empire they followed the boundaries of his Turkey map. (1679). They never tried to combine the two or to find which was correct.

The only important cartographers who did not copy Sanson directly were the Visschers of Amsterdam. The earlier maps of the senior Visscher are based on those of Keer and Bertius, but he had worked for Blaeu whose material is also incorporated in them. Visscher's maps were later copied by the Overtons in England. The younger Visscher's map of Turkey was based on Sanson's map, but was covered with a system of fifteen regions, more detailed than that of Gastaldi. Each is separated by a dotted line and termed *Principat*[*us*], with the exception of *Arabia Petraea,* which is termed *Beglirbegatus Bostrensis.* Among those terms which have not appeared before are the *Principati Argiae, Charebedae* (both in *Arabia Deserta*), *Gerrhensis* (Bahrain) and *Sabae,* which covers the area of Zabid. Peculiarities are the location of *Iemeni Princ*[*ipatus*] in the south-east, while *Oman Princ.* is well to the west of it in the centre of the Peninsula;

and also the division of the Hijaz from north to south, where the coastal strip is called *Princ. Meccensis,* and the inland strip, with Najeran as its largest town, *Higiazae Princ.* Matthew Seutter copied this map and added yet another region, Bahrain, which belonged to Persia.

The foundation of the *Académie Royale des Sciences* in Paris and the *Royal Society* in London, as well as similar institutions in other capitals of Europe, led to the encouragement of travel and astronomical science, and to increasing accuracy in the making of maps. De L'Isle was the first cartographer of this new age, and with his maps comes a new step in the cartographic representation of Arabia.

A summary of the geographical knowledge of Arabia, and also a criticism of the current maps, can be read in the translator's preface to *A Voyage to Arabia Foelix* (1742), the English translation of La Roque's book. The author of this note states that De L'Isle used Idrisi and Abu'l Feda, and other Arabian geographers. He finds, however, that the use of the few others who were known to Europeans at the time could have added little to the information given in the extracts of Idrisi and Abu'l Feda. De L'Isle was only acquainted with Abu'l Feda in the translation of La Roque. It must, therefore, be assumed that he had no knowledge of the variant versions of longitude and latitude given for places by Abu'l Feda. D'Anville, fifty years later, had probably met Greave's translation, for he quotes his use of *Nassir Eddin* and *Ulubeg* in his memoir on the Persian Gulf. The odd scraps of information accumulated by the new societies, and probably never recorded, helped a great deal to provide a basis on which to work, and a standard by which to gauge the accuracy of the Muslim accounts.

De L'Isle's most detailed map of Arabia is the *Carte de la Turquie, de l'Arabie et de la Perse,* which appears in his atlas, and in its earliest state the plate is dated 1701. He also produced a map of North-West Africa, first dated 1707, which includes the whole of the Arabian Peninsula; this is not quite as detailed, but on a slightly larger scale.

The Peninsula in these maps takes on the features which are familiar to all who use modern maps. The most prominent of these is the lack of detail for the central south, the area of the Rub' al-Khali. The main range is placed near the Red Sea coast, and another fills the central south. This, called the *Gebel el-Aredh,* follows a general south-westerly direction from *Iemama* and corresponds to the Jebel Tuwaiq. The mountains of Tai also appear, in the form of *Haja* and *Salma,* with *Faid* between them. (Gastaldi had placed Faid south of Yamama. Later cartographers moved it further east with the result that for centuries it remained south of the Persian Gulf). This is the first time that it is placed correctly. All the main northerly settlements are roughly in position, but Jauf is absent and Taima (as *Tima*) is too far to the south-east, as in Sanson. In the south the *Royaume du Caresen* appears with its capital at *Caxem, Kasel* or *Caresen,* all of which are merely versions of the modern Qishm. Two detailed routes appear in De L'Isle's map, but the sources of these are unknown. One is from San'a northwards through *Saada* and *Sadium* to *Niab,* and the other is from *Tayef* eastwards to *Iemama* via *Caraiathaim.*

De L'Isle simplifies the political division of Arabia. He has the land of the Sherif of Mecca, including Yamama and Najran. South of this he divides off the Tehamah and the tribal area of *Chaulan* and on the south coast *Hadramut* and *Seger* with *Caresen.* Finally, he separates that section of the Bahrain coast which belongs to Persia. He makes the Yemen cover the whole of the south of the Peninsula.

Another map attributed to De L'Isle is that of Yemen which appears in La Roque's *Voyage de l'Arabie Heureuse.* A French commercial expedition sailed to Mocha in 1710, desiring to profit by the coffee trade. Two surgeons from the expedition entered Yemen

at the request of the Imam of San'a. Their swift journey through the country and back is related at second-hand by La Roque, and this map was drawn to illustrate their journey. It is a very bad map which, although showing the important places and the route of the *Voyage,* has most places far from their correct positions. The translator of the 1742 English edition criticizes it, especially the fact that San'a is much too far to the south.

It is interesting to note that about this time rivers are shown which become dry before reaching the sea. De L'Isle's map of Turkey, for example, shows *Tebala* on the *Sansan* River, which flows from the Hijaz range into the desert. The map of Yemen has as many as six similar streams, but none of them are named.

De L'Isle became the model for most succeeding cartographers, the most important of whom were Moll and De Fer. Moll followed De L'Isle closely in detail though not in general shape of the Peninsula. He also added the pilgrim route from Basra to Mecca. De Fer (1715) goes back to earlier maps and inserts material from them in the blank spaces of De L'Isle's map. Thus *Amanzirifdin, Alibinali* and *Guebelhaman* appear again.

One other strange map worth mentioning is that drawn by Abubekir Efendi for the book *L'Etat Militaire de l'Empire Ottoman* by the Comte de Marsigli in 1732. This map is very badly drawn but has the advantage of being the first map of Arabia in a European language to be compiled by a Turk. The coastline was probably taken from the maps of Sanson, but no interior detail is given other than the Hijaz range and the political divisions. These are the *Gioba* (Sherif of Mecca) and *Yemen* or *Arabia Felice. San'a* and *Gidda* are separated from the rest, indicating their individuality as headquarters of Turkish garrisons. Under the term *Yemen,* Abubekir includes all Arabia south of the Tropic of Cancer.

The climax of what might be called "Medieval" geography came with the great map of Asia published by D'Anville in 1751 (Fig. 2). The sources of D'Anville are easily located, for a certain amount of information has been published in various *Mémoires* of the *Académie Royale des Inscriptions.* In a report given to the *Académie* after the Danish expedition of Niebuhr, it is stated that D'Anville's main sources for Arabia in his Asia map were the geographies of Idrisi and Abu'l Feda, and the *Jihan-numa* of Katib Chelebi, of which there was a French translation in the *Bibliotheque du Roi.* It can be seen from this report, and from practically any other account of D'Anville's work, that he was intensely interested in the classical geographers. It was his comparison of these with the work of the Arabs and with European travellers that gave him a clearer view of the Peninsula as a whole than his predecessors had achieved. In his memoir on the Persian Gulf and description of the Red Sea, he quotes the manuscript material at his disposal when he was compiling this chart. Most of this seems to have been in his hands before 1750, and was probably used for his map of Asia. It consists of a Turkish marine chart, several manuscripts belonging to Melchisédec Thévenot, a plan of various ports made for the fleet of Estevão da Gama, and two manuscript maps with journals attached, one in English and the other in French, made for the *Compagnie des Indes.*

The changes made in De L'Isle's representation are very numerous, although not always for the better. D'Anville's map is virtually blank except for one or two parts. The Hijaz coastal region is fairly detailed, and this detail continues through the Yemen to the Hadramaut. Other detailed spots are Dhafar and Oman, and a narrow band from Mecca through Yamama to the Persian Gulf. South of this band are "very dry deserts" (English edition of 1755), whilst to the north, the important places have been put into position mainly from Arabic sources. The map is also more profusely scattered with tribal names than were the earlier maps.

Survivals from the earlier maps are quite common. *Mascalat* appears as a large town in an otherwise completely blank section of the Persian Gulf coast, *Vodana* is on the *Moiesur* R[ivière] in Oman, and Seger is still a regional name, but placed further east, in the Dhafar area. *Ialamlam* has reached a more correct position after De L'Isle's successors had spread it across the south, whilst the mountains of *Ared*, which De L'Isle had himself marked across the south, have retreated to the narrow strip of land between Mecca and Yamama, and hence can no longer be equated with the Jebel Tuwaiq. D'Anville, after comparing other sources with Ptolemy, came to the conclusion that Ptolemy was right, and that the river of San'a did not reach the Indian Ocean, but his map of Asia clearly shows this river emptying its waters into the sea east of Aden. Likewise, his river at Yamama, called *Astan*, reaches the sea near the Bahrain Island. (Compare this with Sanson, whose *Astan* follows the Wadi Rumma). An error of D'Anville is the direction which he gives to the river at Tabala, which De L'Isle caused to flow north-east into the desert. D'Anville makes it flow south. A fairly detailed comparison of D'Anville's map with a modern map has been made by D. G. Hogarth[1] so that this aspect need not be mentioned at length here.

It was the production of D'Anville's map which showed the Western world its ignorance of inland Arabia. The desire to correct this ignorance led to the first scientific expedition into the Peninsula, for scholars realized that a number of biblical and geographical questions might be solved by such an expedition. The idea was mentioned to the Danish king, Frederick V, who ordered a list of questions and instructions for the explorers to be drawn up, and in 1761 a Danish expedition set out with Carsten Niebuhr as its leader, and with D'Anville's map as its guide. The expedition was not the success it might have been, but it brought back much topographical information concerning Yemen. This appeared in the maps accompanying Niebuhr's account, which was first published in German in 1772. This expedition was the forerunner of many more and an incitement to other Europeans to explore further the inland deserts of the Peninsula, so leading to what might be termed the modern age of Arabian cartography, when Europeans sought to obtain their information at first hand instead of relying on the out-of-date accounts of Greek and Arab geographers.

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ADINANDRA BĚLUKAR[1]

A Succession of Vegetation from Bare Ground on Singapore Island

By R. E. HOLTTUM

MUCH OF THE forest in Singapore was cleared a century and more ago, first for planting pepper and gambier, succeeded by abandonment of the land, and later the planting of other crops, including rubber. The land which is not now occupied by buildings nor under cultivation is very varied in its history and in the vegetation which covers it. This vegetation includes many alien plants, some of recent origin, which further complicate the situation.

There is however one type of vegetational succession from bare ground which is very characteristic and which consists only of native Malayan plants. It is slow in development and limited in the number of species concerned, some of them of considerable biological interest. Early stages in this succession can be seen on the hills round the Gap (the gap through which Buona Vista Road crosses the recently named Kent Ridge). Later stages occur in many parts of the water catchment area.

This vegetation develops on undulating ground which has been cleared and abandoned, so that all or most of the humus-containing soil has been washed away, and the surface more or less compacted by heavy rain. In 1922–3, when I first remember the hill east of the Gap, it was covered with stunted rubber trees. Many of these trees had already died; others had considerable lengths of tap root exposed by erosion of the top layers of earth. All the trees have now died, and most of the area (as also that part of the ridge west of the Gap) is covered with scrub. In the most exposed places the scrub is not yet continuous; in some other places it has at some time been destroyed and further erosion of the surface has been succeeded by a repeated invasion of the pioneer plants. The luxuriance of the scrub growth varies a good deal in different parts of the area. The most luxuriant growth is on the slopes below the houses now built along part of the ridge; probably a certain amount of waste material of organic origin washed down from these houses helps in the growth of the scrub.

PIONEER PLANTS

On Kent Ridge, the pioneer plants in the most exposed places are *Eriachne pallescens,* a small, tufted, perennial grass with very narrow inrolled leaves. *Gahnia tristis,* a sedge with tough narrow leaves, a much larger plant than *Eriachne,* is also a pioneer where some sandy soil accumulates, and can be very vigorous. A second sedge, *Scleria laevis,* is occasional in the scrub, but doubtfully a pioneer plant. The common Rēsam fern (*Gleichenia linearis*) is unable to establish itself in the most exposed places, but, having grown from a spore in a sheltered place (e.g., under the shelter of an overhanging stone) it can spread by means of its slender, creeping rhizome over quite bare ground. In such places, where the soil contains no organic matter and exposure is extreme, the *Gleichenia* remains very stunted, but it can continue to grow and to give some shelter to other plants. The common Club-moss, *Lycopodium cernuum*, sometimes appears at an early stage and may ultimately be abundant in long-persisting scrub, but it is not always

1. *Bĕlukar* is the Malay name for secondary jungle or scrub.

present. Nobody has yet established (in Malaya) the exact conditions under which this species begins to grow from spores, as its prothalli are very difficult to find. A species which is notoriously common in open ground in Malaya, the lalang grass (*Imperata cylindrica*), is quite lacking in the scrub on Kent Ridge, though it may be found on grass verges beside the new roads that have been made to give access to the houses on the ridge; the same is true of some other common grasses.

Woody Plants

Woody dicotyledonous plants appear at an early stage, sometimes on quite exposed bare ground, sometimes where there is a little shelter already established by other plants. The exact conditions under which each can develop have not been observed, and much remains to be discovered about the early seedling stages. Some of these plants are shrubs, some ultimately grow into trees, but all are very slow in developing, probably owing to the poverty of the soil (at least in part) and together they form a bushy scrub, varying in height and composition. The trees which ultimately dominate this scrub (as judged by later stages seen in the catchment area) are *Adinandra* trees; and these are among the earliest woody plants to be established. The most frequent of the woody plants are dealt with separately below.

Melastoma malabathricum or **Sĕndudok.** This is probably the commonest woody species in open places everywhere in Malaya, and it is decidedly variable. Its very numerous small seeds are distributed by birds which eat the fleshy fruits. In poor soil and exposed places, *Melastoma* grows slowly into a small bush which persists until smothered by taller or stronger plants. It is common in the *Adinandra* scrub, and can be a pioneer on bare ground.

Ficus alba (*Moraceae*). This forms bushes of variable habit, usually quicker in growth and more open in branching than *Melastoma;* it also has small fleshy fruits containing many small seeds. *Ficus alba* is less abundant than *Melastoma,* and probably will not grow in such exposed places.

Adinandra dumosa (*Ternstroemiaceae*) or **Tiup-Tiup.** This forms slow-growing trees of upright habit, ultimately attaining as much as 50 or 60 ft. in height. Plants begin to flower and fruit when only 3 ft. tall, and thereafter flower continuously for the rest of their lives. The seeds are small, in fleshy fruits; Corner says they are distributed by bats[1], but perhaps also by birds. The smallish leathery leaves, without evident side-veins, rather pale in colour, on straight ascending branches, give the young trees a characteristic habit.

Fagraea fragrans (*Loganiaceae*) or **Tĕmbusu.** Seedlings of this species are abundant on Kent Ridge, but trees are not common in the developed *Adinandra* forest of the catchment area. *Tĕmbusu* trees ultimately attain a greater height and spread than do *Adinandra* trees; but unlike *Adinandra* the young trees do not flower and fruit from a very early stage, nor continuously. Though *Tĕmbusu* trees are common in Singapore, and seasonally large quantities of seeds are dispersed by the bats which eat the berries, I have never seen secondary forest dominated by them. If the area on Kent Ridge is left undisturbed, it will be interesting to see whether the *Tĕmbusu* trees ultimately dominate the *Adinandra* trees, or are suppressed.

1. E. J. H. Corner, *Wayside Trees of Malaya,* Vol. 1 (Singapore, 1951), p. 626.

Fig. 1. General view of the scrub on Kent Ridge. In the foreground on left, *Gleichenia* and *Gahnia;* the large-leaved shrubs are *Wormia.*

Fig. 2. Pioneer plants on secondarily eroded area: on left, stunted *Gleichenia;* to right of central boulder, *Eriachne.* The taller grass-like plants are *Gahnia,* the large-leaved shrubs *Wormia.*

Archytea vahlii (*Ternstroemiaceae*) or **Riang-Riang.** This species grows especially in wet ground, but seedlings are quite common in the scrub on Kent Ridge. Older trees are to be found near the edge of the Mac Ritchie Reservoir, seedlings developing in the marginal area which is periodically but not continuously inundated. Plants of *Archytea,* like those of *Adinandra,* flower at an early stage, but less freely than *Adinandra.* The fruits are dry, not fleshy, and dehiscent; the small seeds are probably wind-dispersed.

Myrica farquhariana (*Myricaceae*) or **Tĕlor Chichak.** This forms slow-growing, bushy trees which flower when about 6 ft. high. The small fleshy fruit contains one seed in a thin shell; this is presumably bird-dispersed. Trees are nowhere abundant in Singapore, but seedlings are occasional in the scrub. The leaves of seedlings are deeply lobed, those of larger plants entire.

Wormia suffruticosa (*Dilleniaceae*) or **Simpoh Ayer.** This forms small bushy trees with large leaves and large yellow flowers, and in general occurs in wet ground in open places. Seedlings of this *Wormia* are quite abundant on Kent Ridge. Quite small bushes will flower; the flowers are followed by star-shaped fruits displaying bright red, fleshy arils surrounding the seeds; the seeds are thus dispersed by birds. *Wormia* will probably be overtopped by *Adinandra* on Kent Ridge, but perhaps not suppressed. The reason why *Archytea* and *Wormia,* both normally species of wet ground, grow on these hill slopes is probably that their roots can tolerate poorly aerated soil (*Tĕmbusu* also has this quality) and can grow anywhere if there is enough water in the soil. They will not grow in very sandy places where the soil dries quickly after rain, but they will grow in soil containing some clay which is poorly aerated and has a surface compacted by heavy rain.

Rhodamnia trinervia (*Myrtaceae*) or **Mĕmpoyan.** Young trees of this are occasional in the scrub; they grow about as fast as *Adinandra* but do not fruit early. The fruits are berries containing small seeds, distributed by birds.

Macaranga javanica (*Euphorbiaceae*). Trees of this are abundant in secondary forest in Singapore, and occasional seedlings occur in the scrub on Kent Ridge. They are recognized by the rusty twigs and long-stalked, ovate leaves; the small-flowered inflorescences are on the bare twigs below the leafy parts.

Pitcher-plants and Orchids

Both Pitcher-plants (*Nepenthes*) and orchids, particularly *Bromheadia,* are conspicuous in the *Adinandra* scrub, and both are of considerable biological interest. Both are slow in developing, and need prolonged exposed conditions for full development.

Nepenthes is a genus characteristic of the Malayan region. In Malaya there are two distinct groups of species, one group in the lowlands, one on mountains. They only grow where there are prolonged or permanent open conditions; thus their permanent homes are the sea-coast where this is steep (as at Labrador, Singapore) and the high mountain ridges where no tall trees will grow in the acid peat. The *Adinandra* scrub provides conditions which suit *Nepenthes* plants, giving them shelter for their roots and a place in the sun for their climbing stems for a long period. It should be noted that the habit of *Nepenthes* plants in catching and digesting insects (especially ants) provides them with substances normally taken up by roots but inadequately available in the poor soils of the exposed places where *Nepenthes* plants grow.

Nepenthes seeds are very small, and are wind-borne; they have a short period of viability. They germinate in wet weather on bare ground, or in slightly sheltered places; young plants are not common on Kent Ridge. The seedlings at first form rosettes of successively larger leaves, each leaf ending in a broad-based pitcher which rests on the ground. When the rosette of leaves is well grown, the stem begins to elongate, and climbs by tendrils formed at the ends of the leaves (a pitcher sometimes beyond the tendril). The climbing stems from time to time (not continuously) bear terminal inflorescences of small unisexual flowers. These flowers are evidently pollinated, as the fruits are always formed and always full of seeds. The agents of pollination are perhaps ants, but this is not certain, and no considerable number of insects have been seen visiting the flowers. The sepals of both male and female flowers are covered with small glands, which produce nectar when the flowers are newly opened and pollen is shed; this nectar is surely attractive to small insects, including ants, which also visit the nectar-producing glands on the lids and rims of the pitchers. The stimulus to flowering, which is at irregular intervals but gregarious, is probably dry weather following a wetter period.

The pitcher plants scramble over the bushes and small trees in the scrub. They persist for a long time when the scrub has grown up into forest, but they cannot establish themselves from seed in deep shade. The species are *N. rafflesiana, N. gracilis* and *N. ampullaria.* The hybrid *N. ampullaria* × *rafflesiana* is common; the hybrid *N. ampullaria* × *gracilis* is rare. *N. ampullaria* persists longest in the developing *Adinandra* forest. Where the older parts of its climbing stems trail along the ground, they produce large groups of pitchers on short lateral branches, and such groups of pitchers are very abundant in some parts of the catchment area forest in Singapore.

The only abundant orchid in the *Adinandra* scrub is *Bromheadia palustris.* Each plant produces a tuft of erect leafy stems, each stem terminating in a slowly elongating inflorescence which bears fairly large, white flowers, one at a time. The flowers last only a day, and there is a fairly frequent gregarious flowering, with a few casual flowers on days between. A discussion on the causation of the gregarious flowering, which is a complex phenomenon, is given by Holttum in *The Gardens Bulletin,* Vol. 12 (Singapore, 1949), pp. 295–302. *Bromheadia* flourishes where its roots are sheltered by the shade of other plants but its leaves and flowers are exposed to the sun. Its short roots do not penetrate the soil deeply, and are like those of epiphytic orchids. Most of its near relatives are epiphytes, and it is probably to be regarded as an epiphyte which has come back to earth.

Spathoglottis plicata and *Arundina graminifolia,* the commonest terrestrial orchids of open places in Malaya, also occur occasionally in the *Adinandra* scrub, but neither is abundant. Other less common orchids are *Habenaria sumatrana,* a small white-flowered species, and *Dendrobium lobbii. Dendrobium* is a large genus of epiphytic species; *D. lobbii* is one of the very few which are terrestrial, and like *Bromheadia palustris* may be regarded as an epiphyte come down to earth, which has found shelter enough for its roots, and a sufficiently prolonged period of open air and sun on its leafy stems, to permit development in this scrub. I have only seen it elsewhere in silt in a wide open stream-bed in Johore, where it was subject to occasional flooding.

Later Stages of the Succession

Nobody has observed the full development of the succession from bare ground to tall *Adinandra* forest. The scrub stage certainly may last more than twenty years; the length of time no doubt depends on many factors, one always being the poverty of the soil in some particular element or elements.

As noted above, later stages of what is surely the same succession may be seen in the catchment area, where *Adinandra* is dominant but some of the scrub species remain in the undergrowth. In 1930–40 there were very large areas of dense, almost pure *Adinandra* forest; many of the *Adinandra* trees were felled for use as poles just before and during the war, and good examples of pure stands of *Adinandra* are now not so easily accessible, though many areas where *Adinandra* is dominant remain.

Adinandra does not cast a very dense shade, and both *Gleichenia* and *Nepenthes* may persist in the undergrowth when the trees are quite tall, neither so vigorous as at the scrub stage. The *Nepenthes* climb quite high up the *Adinandra* trees, to bear their flowers in exposed places. *Bromheadia* also persists, its stems taller and weaker, flowering little. Tree seedlings of other kinds gradually appear, such as will tolerate shade, but their development is slow and no systematic observations have been made. The seeds from which these plants grow must come from the remaining patches of primitive forest; the dispersal of such seeds is often less efficient than the dispersal of seeds of trees of *bĕlukar*.

Locally in Singapore Island (in the catchment area and elsewhere) are dense thickets of *Gleichenia* with little or no tree growth. It is probably impossible for any tree seedling to establish itself in these thickets, and the co-existence of *Adinandra* and *Gleichenia* in the *Adinandra* scrub and *bĕlukar* is due to the fact that the *Adinandra* seedlings become established before the *Gleichenia* becomes a dense thicket; probably also due to the fact that in extremely exposed places the early growth of *Gleichenia* is slow. Once the *Adinandra* plants have grown into trees, their shade weakens the *Gleichenia*, which needs full sunlight for strong growth.

Geological Nature of the Underlying Rocks

The scrub on Kent Ridge is on sandstones and shales, which undoubtedly give a very poor soil, deficient in potassium and phosphorus, and perhaps in other elements also. *Adinandra* scrub and forest have, however, developed also on granite soils where these have been impoverished by cultivation and exposure, leading to erosion and leaching. One must remember that the original forest, growing for some millions of years, had gathered into its own circulating system a large part of the accessible mineral resources of the soil (especially of elements in short supply), and the first thing men did was to destroy the forest, so that much was lost before the processes of erosion and leaching got to work. It seems probable that a common feature of the plants of the *Adinandra* scrub is that they can live, not only under conditions of extreme exposure and of poor soil-aeration, but also in conditions of restricted mineral supply which the majority of plants would not tolerate.

Future Observations

Observation of the development of selected areas of scrub on Kent Ridge would be of considerable interest, some areas in more exposed places than others, and some where *Wormia* is abundant. Similar observations of the development of selected areas of scrub in the catchment area are also desirable. These observations would need to be extended over several years. Experiments to determine the effect of applying lime, rock phosphate and other simple compounds containing necessary plant nutrients would also be of interest, and sand culture experiments of plants of various species in isolation, to test their mineral and nitrogen requirements and rate of growth under different conditions.

Other Kinds of Succession in the Catchment Area

In the neighbourhood of the remaining patches of primitive forest there is a great variety of *bĕlukar*, some of it evidently having developed on ground that has never suffered exposure and erosion. In some areas there is much *Eugenia longiflora*, with species of *Elaeocarpus*, and other trees casting a denser shade than *Adinandra*. There is every kind of gradation from this to high forest; and locally, where there have been more recent fellings of trees without clearing of the ground (as near Lornie Road) there is a varied growth of fairly fast-growing *bĕlukar* trees, including species of *Macaranga*. The situation on such better ground is extremely complex, and I doubt whether distinct successions can be made out.

MIXED-GARDEN HORTICULTURE IN JAVA

By G. J. A. TERRA

Mixed Gardening in the Agricultural Pattern

One of the earliest descriptions of mixed gardening was given at the beginning of this century by Sollewijn Gelpke (15)[1]. His oft-quoted introduction to the subject begins: "He who enters a mixed garden (*erf*, Dutch; *pekarangan*, Malay, Javanese) with a botanical eye, sees before him a diversity of plants of which the uninitiated can form no idea. From the greatest inhabited heights to the shores of the sea, on clay and sand, in marshes and on dry land, the whole wealth of the tropics is laid open. That wealth of vegetation is all the more striking when the observer regards it from an economic point of view. He sees palms, bamboos, bananas and a number of fruit trees, all seemingly much alike and with various winding plants clinging to them". Somewhat later Willis (32) wrote of Ceylon: "A conspicuous feature in native agriculture throughout southern Asia, which often offends the eye of those who have a superficial acquaintance with European agriculture, is the wild jungle-like mixture of fruit trees, bamboos, vegetables, etc., which forms the average native garden". Willis also introduced the terms "mixed garden" and "mixed gardening", which are used here in preference to "compound", "enclosure", "homestead", "yard", and suchlike, for these latter are not always planted and may be quite bare.

These two examples indicate the wide range of mixed gardening in South-East Asia; it is, however, not typical of all this region. It occurs in Ceylon; on the Malabar Coast; in southern Burma; in the Khassi region of Assam; on the Tenasserim Coast and the frontier regions of Siam and Malaya; in other parts of Siam, such as the Lawa district, near Chiengmai; in Cambodia; and as a relic from Cham times in Annam; and also in some parts of the mountain ranges between Annam and Cambodia. Mixed gardens are also found in Malaya, especially in Negri Sembilan. In Indonesia they are typical of Central Java, and also of Achin, Minangkabau, and some parts of Benculen and Lampongs (Semendo). They have spread from Minangkabau to the south of Tapanuli (Mandailing), from Central Java to the western Sunda country, and in the east to the eastern part of Java, Madura and Bali, and even to the Macassar region and Ambon. They are also reported from various isolated regions: Bantik (Manado), Sangihe, Talaud, Sula, Muna, Kisar, Enggano, and even from the Belu country in the south-east of Indonesian Timor (though on aerial photographs most of the villages there appear as agglomerations of houses without any tree growth between). Nowadays, in all coastal towns and interior administrative centres mixed gardens are common, though in the rural districts they are still mostly absent. It seems, moreover, that they are to be found even in some Polynesian and Micronesian regions, e.g. Lukunor (17) and Palau (1), and they are reported also from the Mexican west coast and from the West Indies (Willis).

Though the dense, jungle-like mixture of plants looks strange to the European eye, the practice is not unknown to the West, and is, in fact, in some forms already advocated by Russell Smith. Before we can achieve a comparison with European conditions we still have to mention another feature of these mixed gardens: they always belong to, and surround, separate houses and are mostly fenced off from neighbouring mixed gardens.

1. Figures in brackets in the text refer to the references on pp. 42-3.

Together they form the villages, though separate homesteads may occur, as on the Malabar Coast, at Maros in South-Western Celebes, and in Madura and East Java. This is also true of Europe, where Hahn (5) has already pointed out relics of a hoe culture of tubers, grains and herbs, and drawn attention to the dominating influence of the housewife in the kitchen gardens. Both these features are derived from an older agriculture where women tended the crops. In Africa the natural, unplanted compounds of the Nigerian Ibo peoples described by Leith Ross may be similar in origin, as may the *jardins des femmes* of Chevalier.

It is readily understandable that mixed gardening is only to be expected in regions where individual ownership—or at least family ownership—of house and house site is one of the cultural traits. In such cultural systems all the arable land is usually owned individually or is in the hands of the family, though the community as a whole may possess supervisory rights. In regions where communal ownership prevails, that is, in most regions of shifting cultivation, even the house sites are communally owned and mixed gardening is impossible. Then the village often consists either of rows of adjoining houses around a square or along a broad street, or else is formed of a dense cluster of houses. In both instances the villages are frequently surrounded by thick plantings of trees, communally owned but with individuals possessing rights over certain trees or sections (as in Annam or among the Batak); or additional forest-like groves (for example, sago gardens) are to be found in the neighbourhood, and are owned by certain clans or families (e.g. in Ambon and Ceram). These gardens are not of universal occurrence (e.g., they are lacking among the Badui in Banten). Sometimes clumps of trees in individual ownership are found outside the villages. These have been planted in former *ladangs*[1] to denote a right of priority (Palembang).

In the typical mixed-gardening regions arable land consists of mixed gardens and wet padi-fields (*sawah*), and in Java also of dry fields (*tegalan*), in varying proportions. *Ladangs* are generally lacking. In areas of shifting cultivation *sawahs* may occur as an acculturation feature, but *ladangs* and communal groves preponderate, while mixed gardens are either absent or are recent introductions. There is still insufficient information available for us to say very much about those regions where a primitive hoe culture of tubers and grains (*keladi*, yams, millets) in more or less permanent gardens prevails (e.g. Nias, Mentawai, Enggano, Sangihe, Talaud, Bantik, Muna, Sula, Tanah Ai on Flores, the Kodi region on Sumba, the Belu country in Timor). Conditions seem to vary with the type of acculturation, but mostly the house sites are owned by families or individuals, yet formerly were not planted (e.g. Bantik, Talaud). Plantings of fruit trees are common but sufficient data on the site and status of these plantings are not yet available.

The Significance and Function of Mixed Gardening

In Java in 1940, of a total of 8 million hectares of arable land in use for Indonesian (peasant) agriculture, 1·5 million hectares were under mixed gardening, 3·4 million under *sawahs* (wet fields) and 3·1 million under *tegalans* (dry fields), so that mixed gardens occupied 18·7 per cent of the total. In Central Java more than 22 per cent of all arable land consisted of mixed gardens, against 15 and 17 per cent respectively for West and East Java. The figures for other regions in Indonesia are not known.

Sollewijn Gelpke had early noted that these mixed gardens played an important part in the peasant economy, as they produced fruits, tubers and vegetables throughout the year, both for the daily menu and for bartering or selling on the local market. Thus some

1. Planted clearings.

income was assured at all times. Willis pointed out the advantage of growing a mixture of the old familiar crops on the same land for an almost indefinite period, and therewith disposing of the necessity of rotation. De Vries (31) emphasized the difficulties in a peasant subsistence economy of producing the necessary items of daily diet in separate fields. Thus, variation and quantity dominate over the modern demands for uniformity and quality.

In an economy of market production separate lots can be employed to produce large quantities of a product of uniform quality, but in a subsistence economy a continuous flow of small quantities, suitably varied, is to be preferred, for the production of large amounts of easily perishable horticultural products results in unavoidable losses. Moreover, the system offers opportunities for the modern horticultural practice of interplanting shrubs, creepers, annuals and especially trees, which do not come into production for some time, without reducing seriously the total yield. This may be lowered, but non-producing fields are avoided, which is a great advantage in a society without capital or reserves to bridge non-productive years. This is even more true when the farm units are small, and in Java they average not more than one or two hectares, and on the other islands are not much larger.

When in 1930 in Java horticultural technique was so far developed that most trees could be propagated true to type on a large scale, the question of the exact function of mixed gardens became of great importance. Was it desirable to follow European methods and concentrate the production of fruits and vegetables in orchards and separate fields, or was it better, under the existing circumstances, to promote, extend and modify mixed gardening? In an attempt to solve these questions Ochse and Terra (11) started a budget and diet investigation in a Central Javanese mixed-gardening region at Kutowinangun[1]. On these former marshlands, now rich, well-irrigated sedimentary soils with an average of 13·3 ares of arable land per head (6·7 ares of *sawah*; 3·6 of mixed gardens[2] and 3·0 ares of *tegalan*), and with more than 440 fruit trees per hectare of mixed garden (166 coconut palms), the *sawahs* produced 5·15 million calories and 113·5 kg. of proteins per hectare in three crops (west monsoon rice, east monsoon rice, and pea-nuts or soy-beans between). The mixed gardens produced 4·5 million calories and 58·5 kg. of proteins per hectare; and the *tegalans* 4·15 million calories and 53 kg. of proteins, mostly from manioc.

Generally, the best and most easily irrigated soils are in use for *sawahs*, the higher strips between them, together with the foot hills, for mixed gardens and *tegalans*. Owing to the high prices of coconuts in the years between 1900 and 1930 (Van Doorn), coconuts preponderate in the mixed gardens and account for the high level of calory production; but after 1930 the formerly very high cash returns of these mixed gardens dropped below those of the *sawahs*. The dry fields, planted principally with manioc, still produce significant quantities of protein, but the percentage is so low that use of manioc as a principal food results in far too low a protein intake. The value of the production was U.S.$31, $20·5 and $14·5 per hectare for *sawahs*, mixed gardens and *tegalans* respectively. In one series of observations the *sawahs* produced 73 per cent of the calories and 80 per cent of the proteins, the mixed gardens 18 and 14 per cent respectively, and the dry fields 8 and 4 per cent.

1. Mean length of the dry period (less than 60 mm. of rain), 3·6 months; total rainfall, 2,531 mm.; height above sea-level, 11 m.

2. 27 per cent of the total arable land.

The local diet was based on the local agricultural system. It provided 1,600 calories per day per head (basal metabolism ± 900 cal.), derived from 285 gm. carbohydrates, 40 gm. protein and 33 gm. fat (mostly coconut). It included, among other items ± 290 gm. of rice, but at the same time at least ± 120 gm. fruits and vegetables, of which 55 gm. were greens and young pulses,[1] mostly produced in the mixed gardens. Animal protein amounted to only 3·5 gm.

Other regions where, partly for some ecological reason such as a drier climate, and partly for some ethnological reason, mixed-garden horticulture was much less well-developed, had in consequence a diet with fewer fruits and vegetables (12, 19, 20). In general the production of vegetables per hectare of mixed garden can be estimated at 500–1,000 kg.; the production of fruits on the average will be similar, but rather more variable. The remainder consists of some tubers (*keladi*, yams, arrow-root) and of coconuts, kapok, areca, betel, firewood, bamboo, herbs, etc.

For comparison one series (Karangbinangun) is given from the Gresik district (12)[2]. In these low-lying regions, with a rather dry climate and margalite soils, mixed gardening is not developed. The average area of land per head is 15·3 ares, of which 13·4 ares are *sawahs*, 0·9 are mixed gardens and 1·0 *tegalans*. The diet was found to contain 1,113 cal. (30 gm. protein, 11·4 gm. fat, 222·5 gm. carbohydrates (bas. met. ± 900), derived from 246 gm. rice and maize and, among others, 37·4 gm. of fruits and vegetables, of which only 11·7 gm. were greens and young pulses.

Thus the function of the mixed gardens seems to be to supplement the diet with varied proteins; with vitamins (A and C), with mineral constituents and flavourings and spices. Moreover, they produce medicinal plants (e.g. *Datura*), firewood and bamboo. The result is a continuous source of materials for side dishes and a small, but steady flow of income from the sale of surpluses in the local markets. Also, the tubers form a reserve for poor times (yams, etc.). Normally a mixed garden, apart from harvesting for daily use, needs only a few days' labour each year. Large cash incomes are obtained only when a great deal of labour is expended on picking and marketing, and occur, for example, in the vicinity of the towns.

The Assortment and Distribution of Plants

The oldest plants of the mixed gardens were already to be found in that primitive form of grain-less hoe culture, on permanent or semi-permanent fields, which spread over Polynesia. Such plants are the banana and plantain, the coconut, breadfruit, yam, *keladi*, *bira* (*Alocasia*), turmeric, and perhaps sugar-cane and various vegetables, although, in this type of agriculture and also in the hoe culture of grains (millets, etc.), most vegetables were probably still collected in their wild state.

Nowadays the most common fruit trees (6, 8, 9, 10) of mixed gardens in the rainy or irrigated regions of the lower plains are: *Artocarpus champeden*[4], *A. integra*[4], *A. rigida*, *Antidesma bunius*[3], *Annona muricata*[4], *A. reticulata*, *Achras sapota*[3], *Anacardium occidentale*[3], *Averrhoa bilimbi*[4], *A. carambola*, *Bouea macrophylla*[3],[4], *Baccaurea dulcis*, *B. motleyana*, *B. racemosa*, *Cynometra cauliflora*, *Citrus maxima*[3], *C. reticulata*[3], *C. aurantifolia*[3], *C. limon*[3], *Carica papaya*[3],[4], *Chrysophyllum cainito*, *Durio zibethinus*, *Diospyros discolor*, *Dialum indum*, *Eugenia aquea*, *E. cumini*, *E. jambos*, *E. javanica*, *E. malaccensis*[3], *E. polycephala*[3], *Flacourtia rukam*[3], *F. inermis*, *F. indica*, *Garcinia*

1. It would be highly advisable to determine the amino-acid composition of high-protein vegetables, such as the young leaves of *Manihot*, *Jatropha*, *Sauropus*, *Euphorbia pulcherrima*, *Codiæum*, and *Leucæna*, all with from 5 to 10 per cent of protein. They could be very effective in supplementing the rarer amino-acids (lysine, tryptophane, methionine threonine), and thus take over the function of animal protein and reduce the necessary total intake of proteins.
2. Length of the dry season, 5·0 months; annual rainfall, 1,600 mm.
3. Also the young leaves.
4. Also the young fruits.

Fig. 1. A typical Javanese *sawah* area with mixed gardens, between Jogya and Magelang. By permission of *Landbouw*, Vol. 25 (Djakarta, 1953).

dulcis, G. mangostana, Lansium domesticum, Mangifera caesia[1], *M. foetida, M. odorata, Manilkara kauki, Morus alba*[1], *Nephelium lappaceum, N. mutabile, N. longana, Phyllanthus acidus*[2], *Psidium guajava, Passiflora laurifolia, P. quadrangularis, Pithecolobium dulce, Punica granatum, Persea gratissima, Salacca edulis, Sandoricum koetjape, Spondias cytherea, Tamarindus indica.*

The following are planted for their nuts or kernels: *Aleurites moluccana, Inocarpus edulis, Parkia speciosa, Pithecolobium lobatum, Pangium edule, Canarium* spp., and *Gnetum gnemon* also for tops, leaves, inflorescences and young fruits.

Some trees and shrubs are grown especially to furnish vegetables: *Acalypha wilkesiana, Bauhinia tomentosa, Cordyline fruticosa, Cassia laevigata, Codiaeum variegatum, Decaspermum fruticosum, Erythrina variegata, Euphorbia pulcherrima, Lannea grandis, Leucaena glauca*[2], *Moringa oleifera*[2], *Morinda citrifolia*[2], *Maesa latifolia, Nothopanax fruticosa, N. scutellarium, Pluchea indica, Pisonia alba, Pleomele angustifolia, Petunga microcarpa, Rosa* sp. div., *Schefflera aromatica, Sauropus androgynus, Sesbania grandiflora*[2], *Trevesia sundaica.* Sometimes the cabbage is eaten: *Cocos nucifera, Arenga pinnata* (which also yields palm juice), and *Salacca edulis;* while the shoots of the following are also eaten:—*Bambusa multiplex, B. spinosa, B. vulgaris, Dendrocalamus asper, Gigantochloa apus, G. atter, G. verticillata.*

Other trees produce only spices and suchlike: *Areca catechu, Citrus hystrix, Eugenia aromatica, E. polyantha, Myristica fragrans, Piper betle.*

Some of these trees also grow in drier regions, notably: *Artocarpus integra, Averrhoa bilimbi, Aleurites, Anacardium, Psidium, Morinda citrifolia, Tamarindus;* but the typical trees of the drier regions are *Annona squamosa, Aegle marmalos, Borassus flabellifer,* some *Citrus reticulata* varieties, *Corypha gebanga, Mangifera indica, Phyllanthus acidus, Pithecolobium dulce.* On stiff soils with a high water reserve (that is, a large difference between field capacity and wilting percentage) there flourish trees such as *Eugenia cumini, Zizyphus jujuba, Lannea grandis, Aegle marmalos.*

In the uplands at heights above 3,000 ft. only a few trees flourish and produce. Such are, for example; *Cyphomandra betacea, Citrus sinensis,* some varieties of *C. reticulata, Diospyros kaki, Eugenia aquea, E. polyantha, Mangifera foetida, Morus alba, Nothopanax pinnatum, Passiflora edulis, P. ligularis, Persea gratissima* (mostly anise-scented varieties). The exact requirements of *Nephelium longana* and *Litchi sinensis,* which are commonly found in the mountains, are not yet known.

In the wet plains the normal undergrowth still contains bananas and plantains, *keladi,* yams, *bira* and sometimes *Tacca.* The following plants are grown for their leaves and tops: *Amaranthus* spp., *Acalypha indica, Abelmoschus manihot, Alocasia macrorhiza, Celosia* spp., *Cosmos* spp., *Colocasia esculenta, Coleus amboinicus, Clerodendron serratum, Cissus discolor, Dicliptera chinensis, Hibiscus eetveldianus, H. sabdariffa, Ipomoea reptans, Jatropha curcas, Ricinus communis, Solanum nigrum.* For young leaves and fruits, climbers such as *Benincasa hispida, Cucurbita moschata, Lagenaria leucantha, Momordica charantia, Sechium edule, Canavalia ensiformis, Dolichos lablab* are grown together with *Luffa acutangula, L. cylindrica, Psophocarpus tetragonolobus;* and for the fruits only *Trichosanthes anguina, Capsicum annuum, C. frutescens, Solanum torvum, Phaseolus lunatus.*

An important feature in the undergrowth is zingiberaceous plants, the young shoots, fruits, flowers and rhizomes of which are edible: *Alpinia, Amomum, Curcuma, Kaempferia, Phaeomeria* and *Zingiber* species; while often the most important part of the

1. Also the young leaves.
2. Also the young fruits.

undergrowth is formed by tuberous plants, among which *Canna edulis* and *Marantha arundinacea* often dominate, especially under coconuts. Other important tuberous plants of the mixed gardens are *Xanthosoma violaceum*[1], *Ipomoea batatas*[1], *Manihot utilissima*[1] and *Amorphophallus campanulatus.*

It is noteworthy that the following plants are of American origin and have probably spread, more or less spontaneously, from the Philippines: *Achras, Annona, Anacardium, Averrhoa, Carica, Chrysophyllum, Psidium, Passiflora, Persea, Spondias* and *Capsicum, Euphorbia pulcherrima, Hibiscus, Ipomoea batatas, Jatropha, Leucaena, Phaseolus lunatus, Marantha, Manihot, Sechium* and *Xanthosoma,* and perhaps also *Ceiba* (Kapok).

Some bamboos are especially used to make living hedges, notably *Bambusa multiplex,* but also *Ananas, Aglaia odorata, Acalypha, Agavē, Barleria, Codiaeum, Crescentia, Caesalpinia sappan, Cordyline, Hibiscus, Ixora, Jatropha, Pluchea, Pseuderanthemum, Pleomele, Murraya, Nothopanax, Sauropus, Triphasia. Albizzia chinensis, A. falcata, Sesbania* and *Toona* are used for firewood; *Arenga, Cocos, Hibiscus tiliaceus* for cordage; many palms for plaiting; while *Arenga* and *Zea* are also used for cigarettes, and *Phrynum, Homalomena, Hibiscus tiliaceous, Musa glauca, Pangium* and *Tectona* for wrapping.

The annuals in most mixed-gardening regions are generally the same, even the tubers and creepers not varying greatly. They all have their growing season in the rainy period and may even reach their bearing stage at the beginning of the dry season; but by the end of the dry season they have been harvested or have entered a resting period, so that they thus escape the extreme conditions of the east monsoon in the drier parts. The trees, however, are exposed to the varying conditions of the seasons, ranging from extreme humidity and even inundations on the one hand to total lack of rain and cracking soils on the other. Thus, there is a great diversity of trees in the mixed gardens, but a very small assortment of useful trees in the dry regions. Also, above 1,000 metres the choice of trees for mixed gardens is restricted, whilst in the low, rather flat plains the suitability of various trees is determined by the annual variation in the soil-water table. One of the best new trees for high, dry regions is *Ceratonia siligna* (27).

It has been determined (18, 27) that most trees of the low, wet plains may be grown where rainfall is sufficient for the growing of coconuts. Without soil water or seepage water these can stand a dry season of 3·5 months on lateritic soils, which at field capacity have only a small amount of available water, and of 4·3 months on margalite soils, which have a higher reserve of available water.

Some trees, such as *Mangifera caesia, Nephelium mutabile* and *Parkia speciosa,* require much more water and a deep soil; others are, like the coconut, able to grow on reserves of soil water, even if the soil water-table varies with the seasons, *e.g. Achras sapota, Lansium domesticum.* Some other trees may stand a considerable drought, but need good aeration (e.g., *Artocarpus integra*), while most *Eugenias,* for example, especially *Eugenia cumini,* and also *Zizyphus jujuba,* seem to be indifferent to aeration conditions but cannot grow if the soil does not have a high water-reserve. Only a few trees are indifferent to both conditions, e.g., *Psidium guajava.* Bananas and plantains vary in their requirements; *pisang embun* needs much water and air; *pisang radja siem* and *pisang kepok* (and many other plantains) stand much longer droughts. Some trees, such as *Mangifera indica* and many varieties of *Citrus reticulata,* need a dry period for their bearing season.

1. Also the young leaves.

The Distribution of Mixed Gardens

As already mentioned, in Java the greatest extension of mixed gardens and the most intensive planting is to be found in the regions below 2,500 feet, where the dry season is short or absent. This is understandable because a considerable variety of trees flourishes under these conditions. Those regions where soil water or seepage water from irrigated rice fields is available also often exhibit intensive mixed gardening, though the choice of trees is somewhat more limited (22).

Thus, the wet regions of Indonesia, namely Sumatra, Borneo, Celebes and Halmahera, are suitable for mixed gardening, and, where a sedentary population is present, such activity might well be expected. The fact is, however, that mixed gardening is lacking in most of these regions. The higher altitudes might be partly responsible for this, but mixed gardens do not occur even in the lower parts of these regions (such as Gayo, Alas, Batak, Pasumah, Palembang, South Banten, Central Celebes, Minahasa and Halmahera), whilst even an individually owned house site is almost unknown. In many of these regions the people are cattle raisers. One would expect there tropical rain-forests, but those regions are covered with grass, the result of ages of yearly firing of abandoned *ladangs* in order to obtain cattle fodder in the form of young grass. This has promoted erosion so that there is often only a shallow soil cover over the rocks. The peoples in these regions, excepting those of Minahasa and Central Celebes, mostly have patriarchal backgrounds. In the drier Lesser Sunda Islands where these peoples dominate, all forests have disappeared, even in the wet parts (e.g., Ruteng on Flores). Where cattle do not occur (e.g., Alor, Wetar, Tanimbar, Kai) grass fields are scarcer and a light brushwood is still present, even though goats are numerous and the dry season is long. Provisional data about these two features were given by the author in 1949 and 1950 (24, 25).

In the typical mixed-gardening regions peoples are either matriarchal or have a strong matriarchal background[1], (e.g., Central Java, Achin, Minangkabau). The same holds good outside Indonesia, e.g., among the Mon, Khmer, Cham and Khasi, and in Patani and Negri Sembilan (22, 28), where grasslands are scarce.

In the Javanese mixed-gardening regions there is a tendency for the intensity of planting to increase as population becomes more dense, while at the same time mixed gardening occupies a greater proportion of arable soil per head. That is, there is less arable land per head (17). Among European countries, in Holland we see horticulture exhibiting the same tendency with increasing population density. However, in the typical Javanese regions mixed gardens amount to 20–30 per cent of the arable land per head as against only about 10 per cent or less in some western and eastern parts of Java.

These differences cannot be explained ecologically, but must have an ethnological basis. It seems that in the different agricultural patterns found in the Indonesian regions, the conditions under which mixed gardening has developed are indeed very different (29). The shifting cultivators without cattle, usually patriarchal in organization, live in communal villages, often on the tops or slopes of the mountains. The village often consists of a kind of square or broad street bordered with houses, and the whole is surrounded with a strong fence. The land itself was originally owned by the community, as the house sites still are. Mixed gardening is only possible when such villages disintegrate, although communal permanent gardens, planted with trees, may occur.

1. *Matriarchal* and *patriarchal* are used here not in their strict sense, but more as *collectiva* for *matrilocal, matrilineal,* etc.

The shifting cultivators with cattle, more strongly patriarchal, with the single exception of the parental Toradja, show the same tendencies. Communal, clan- or family-owned gardens, planted with trees, surround the village or are spread through the neighbourhood.

In the patterns with a grain-less hoe agriculture the fields are owned by the women folk. This type of village is more varied; usually it is situated in the plains near water courses. Sometimes long houses occur with a communal house site, but it seems that in these matriarchally disposed societies the family-owned house site is not always planted (e.g., Talaud, Bantik, Enggano). Many strange influences may have altered the village pattern (e.g., Mentawai with scattered houses; Nias with houses disposed along a street).

Probably, the cultivation of wet rice was at some time introduced into this pattern (perhaps in Assam). All trees and other plants not able to stand inundation would then be concentrated on the family-owned house sites. This type of culture spread with, or through, the Mon, Khmer, Cham and Javanese peoples, but also reached the Malabar coast of India and the south-west of Ceylon, together with a matriarchal type of culture.

When the Javanese groups reached Java they settled in the wetter regions along the north coast, where a long wet season and less permeable soils were conducive to *sawahs*, e.g., in Banten and from Tegal to Gunong Muriah. From there they filtered into Central Java, absorbing or driving out the patriarchal shifting cultivators with or without cattle, and possibly also still older cultures. Gradually, from Central Java they flowed over to East Java, where they filled up the central part of the area south of the Solo River.

From the great empires which developed here, based on a stable, steadily increasing population with a meagre but dependable livelihood, acculturations spread in all directions, e.g., to Macassar and Bali, and later to East Java and West Java. From other sources *sawahs* and mixed gardens had already reached Achin and Minangkabau (from Champa?).

The original Minangkabau villages consisted of long houses on communal village grounds, while the *sawahs* were family owned. When the nucleated villages disintegrated and people settled on their own plots, they planted mixed gardens, and now even the dry grounds are covered with them (*parak*), while *ladangs* are scarce and *tegalans* unknown. In the similar but more backward Kurintji region the village grounds with their long houses are still communal, while all other grounds such as *sawahs* and *kebuns* are individually owned; but the *kebuns* are up to now inhabited only temporarily. The water wheel (*noria* of the Cham) suggests a Cham or Muong origin.

The family-owned compounds of the grain-less hoe culture have been readily converted into mixed gardens. In West and East Java the communal fruit-gardens have been divided up and used as mixed gardens by erecting houses in them, but in general in the regions of shifting cultivation mixed gardening can only develop where individual ownership of the soil is accepted.

Thus the development of horticulture from the primitive gardens near the houses into the present types of horticulture has not been as simple as De Vries supposed, but has been more intricate and may vary for various cultural patterns.

It is not possible to formulate a hard and fast rule but the historical background seems to be as follows. In matriarchally oriented peoples a strong autochthonous central authority does not seem to develop easily. The clans tend to split up into family groups and these into families, and at the same time the clan-owned arable fields and house sites

become family-owned. There remains a right of disposition by the family-heads and later by the village elders, but this right seems to disappear very easily before the rights over house sites in the normally dispersed and irregular villages.

In patriarchally oriented communities there is a tendency for the head of the principal clan to act as the representative of the community, thus keeping all soils communal property for as long as possible. Conflicts between clans or other units tend to keep the villages readily defensible and thus promote a nucleated form with no room for planting around the house sites. Thus these may remain communal property when other land is already individually owned. In Banjuwangi, where mixed gardening was introduced rather late (in 1850), the new mixed gardens in the villages remained at the disposal of the village whilst the fields outside the village were already owned individually (16).

Thus, the matriarchally based communities offer every opportunity for the introduction of the Javanese type of mixed gardening, but the patriarchal communities reach this stage only after some disintegration. With the parental forms all depends on their background; many of these people are not yet sedentary (e.g., Daya).

In communities with low capital reserves, and under-developed transport and exchange facilities, the mixed gardening type of horticulture is a natural stage of development, and this type of mixed gardening should only be replaced by modern market-gardening—the growing of special products on special farms—when a ready market is present, such as is already the situation near the big cities of Java, e.g., in the surroundings of Djakarta, at the western tip of Madura, near Surabaya, and in the mountainous regions near Bandung, which are suitable for European vegetables and potatoes.

Given this situation, mixed gardening may be a useful stage in the development of many tropical regions where private ownership of the house sites and ecological conditions make this system possible. Under such conditions it should be studied and improved (19, 14). Then mixed gardening may at the same time be incorporated with much advantage into the agricultural system of every farm unit as a protection for the slopes of hilly country. If the lower parts near the river and in the valley bottoms are used for *sawahs*, the gentler slopes can be used for terraced mixed gardens, the trees of which protect the soil; while the steeper slopes can be planted with bamboo and firewood (e.g., ravines of Bali) and the flatter parts used for dry fields, perhaps with rows of trees, bananas and suchlike (*tegal-pekarangan*) and, if sufficient water is available, for *sawahs* also.

At the same time, in infertile areas the soil can be rejuvenated by making the *pekarangan* into an artificial *ladang*, that is, keeping part of the units in rotation under a forest-like growth of mixed garden, in which fruit trees, firewood, bamboo, cacao, oil-palm, etc., can be planted according to circumstance, and gradually thinned out. The deeply penetrating roots[1] bring mineral constituents into the topsoil, the fallen leaves form a protecting mulching cover and bring more humus into the soil, and this cover and the crowns of the trees prevent erosion. After from ten to thirty years, depending again on circumstances, the trees are cut down, the field is sown in with green manures or fodder crops, and after a few years the soil can be used for planting crops. If this system is combined with mixed farming (keeping cattle for labour, manure and meat), the soils obtained in this manner can be kept in a productive state for a long time by using cattle manure, mulch, and perhaps some artificial fertilizers, until a new field finds its place in the rotation. Thus the natural advantages of shifting cultivation can be

1. In Pasar-Minggu, on deep, poor lateritic soils, many tree roots penetrate to a depth of 10 metres (*Cocos*, *Citrus*).

obtained and its drawbacks avoided. This system, which still has to be tried out, meets the difficulties of Gourou who, justly, is not sure that the mixed-farming system will, without more ado, solve all technical problems in the tropics.

It is, for instance very questionable if, on the poor lateritic soils of Sumatra, Malacca[1], Borneo, Halmahera and New Guinea, a mixed farming unit will in the long run be able to export agricultural products with the accompanying loss of mineral constituents, without introducing concentrated food stuffs for its cattle (e.g. copra-cakes) or fertilizers. It is feared that even self-sufficient agricultural units will also eventually exhaust these poor soils. In the proposed system the losses of humus and mineral constituents could thus be compensated periodically. Experiments in this direction have already been started, as is shown by the trials for forest-cultivation of cacao in family-units of about 10 hectares in Surinam.

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1. The Malay Peninsula, which is called *Malacca* by the Dutch.

26. TERRA, G. J. A., *Cultuurtype, landbouw en welvaart in Indonesië* (Inaugural address, Bogor, 1952).

27. TERRA, G. J. A., "Some ecological requirements of Indonesian fruit trees", *Landbouw*, 24 (1952), pp. 193–222.

28. TERRA, G. J. A., "Some sociological aspects of agriculture in S. E. Asia", *Indonesië*, 8 (1952–3), pp. 397, 439.

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32. WILLIS, J. C., *Agriculture in the tropics* (2nd. ed., Cambridge, 1914).

TRADITION AND PEASANT AGRICULTURE IN MALAYA

By LIM JOO-JOCK

PEASANT AGRICULTURE in Malaya shows many ritual practices, largely animistic in nature, which even six centuries of adherence to Islam have been unable to eradicate. Among the best known of these practices is a propitiatory ceremony, accompanied by festivities and the ritual slaughter of goats and buffaloes, which often precedes padi planting[1].

The transplanting of padi is also the occasion of a ceremony conducted by a *pawang*[2]. This transplanting ceremony begins with incantations, after which a square, wooden framework is placed on a selected part of the prepared padi field. The *pawang* plants the first seven bunches of seedlings of the season in the square enclosed by the frame, seven individual seedlings being inserted with the *kuku kambing*[3] each time. With the conclusion of this ceremony, all work on the fields is forbidden for the rest of the day, but on the day following the work of transplanting begins in earnest. This is carried out by women and must be performed in silence. On no account must seedlings, which are held in the left hand, be dropped; and while the *kuku kambing* is actually in use, the tongue of the female worker must be pressed hard against the roof of her mouth. The *kuku kambing* holds from five to nine seedlings at once and is used seven times in succession. During the whole period when the seven bunches of seedlings are being planted the labourer must keep her tongue in this uncomfortable position. These tedious conditions cannot but induce rapid transplanting and suggest utilitarian rather than religious values.

At harvesting there is an even more elaborate ritual. After the observance of these ceremonials, the Malay padi planter is forbidden to work for the remainder of that day and for the two succeeding days. Only after this interval does he begin to reap. The pre-harvest rites include a ceremonial cutting of grain which is already ripe, so that the two-and-a-half day period of enforced inactivity can be disastrous to the standing grain should there be heavy thunderstorms followed by dull sunless weather. Although two and a half days appear to be a short period, it is long-enough for the peasant to bring in a considerable portion of the season's crop from his small-holding. Reaping is very often done with the *tuai,* a small knife used to cut off the grain ear by ear[4]. Although this is a slow, cumbersome method, an experienced woman reaper using a *tuai* can harvest about 700 lb. of padi in a seven-hour day. If the working day is prolonged, as it often of necessity is, the quantity of grain brought in can be appreciably more. If the whole peasant family is taking part in the work of harvesting, then a considerable amount of padi could be garnered in this traditional two-and-a-half day period of rest.

1. G. E. Shaw, *Malay Industries: Part III, Rice Planting* (London, 1911), pp. 7-10.
2. The village medicine-man or shaman.
3. A dibbling tool used as an aid in transplanting.
4. This knife consists of a framework of wood, in the centre of which is fixed a small blade. The wooden framework is held in the hand so as to hide the blade, the underlying idea being that the rice grains shall not see the knife and that their vitality shall not suffer through fright—R. J. Wilkinson, *A Malay-English Dictionary,* Vol. 2 (Mytilene, 1932), p. 604.

The period of inactivity may in some localities be longer than this. Sometimes reaping begins in earnest as long as seven days after the ritual reaping of ripe grain. But there may be sound practical reasons underlying these superstitious observances. The delay in harvesting after the appearance of ripened ears in the fields may possibly serve to ensure full ripening or to allow a greater part of the field to be ripe at once.

There are also ancient rites connected with the other phases of work in Malay padi culture. They belong to the pre-Islamic era and have survived early Islamic disapproval so successfully that prayers by the *kathis* or leaders of the mosques are now accepted as being part of these rites. This suggests that some of them may be well attuned to the local environment and seem to local cultivators to serve a practical purpose. The planting ceremonies take place with the onset of rains and the harvest rites in the dry spells that occur in the period December to January.

The observance of the Islamic lunar calendar by peasants could mean that the religious festivals and rites of Islam would not be well adjusted to the seasons, ill-defined though they might be, of the solar year. Little has been done to trace this possible interaction between religion and seasonal work cycles. The work in the padi-growing areas in Malaya is related largely to the incidence of rainfall and to floods. It is said that, "While these rhythms of activity relate to solar rhythm affecting the rainfall, the local calendar is lunar, and the festivals associated with it are not closely connected with the rhythm of agricultural life of the seasons, a discordance matched also by the Muslim festivals which relate more to Middle East events than to those of South-East Asia[1].

The padi planters of Malaya are mostly "Malaysians", that is, Peninsular Malays and immigrants from other parts of the Archipelago. The latest Census Report shows that 89 per cent of the country's 470,000 padi planters are "Malaysians", who adhere to Islam[2]. This has significant effects on the seasonal cycles of activity, particularly in connection with the observance of the annual monthly fast falling in Ramadan, the ninth month of the Arabic and Muslim calendar. All Muslims are required to abstain from sustenance during the hours of daylight for the whole month, but if a man is on a journey or sick he may "fast another number of days", and if he is able to fast and does not "he may redeem it by feeding a poor man", but "if you fast, it is better for you"[3]. However, the work of crop cultivation is not judged important enough to exempt a Muslim from the fast.

It is to be noted that in the Middle East also the fast is not related to farming and pastoral cycles. It was probably instituted during the second year at Medina when the corrected lunar calendar was in use. This caused Ramadan always to fall in winter, a period of relative inactivity. Later Mohammed decreed the use of the uncorrected lunar calendar, which remains the standard of time for all the Muslim world. It has twelve lunar months each of 29·53 solar days, so that the Muslim year has about eleven days less than the solar year of 363·24 days. Thus each Muslim month goes the round of the seasons in about thirty-three years, and the Ramadan month of fasting occurs at each season of the year in turn. It is obvious that the Muslim calendar is no sound basis for guiding farmers in the timing of crop cycles, which follow the sequence of the seasons.

Observance of the Ramadan fast imposes a severe strain on human endurance if it occurs at a time when strenous physical labour is necessary. The fast, which necessitates abstention from food and drink between sunrise and sunset during each day of Ramadan,

1. E. G. H. Dobby, *South-East Asia* (London, 1950), pp. 109-10.
2. M. V. del Tufo, A Report on the 1947 Census of Population (London, 1949), table 78, p. 442.
3. *Koran*, Sura 2, v. 179-81 (Flügel Edition).

has a marked effect on the efficiency of agricultural labourers. The abstention from water during the long hot hours after 10 a.m. is not conducive to physical exertion in the open, unshaded fields, while the lack of solid food during daylight, although more easily bearable, is still a hindrance to manual labour. It is, therefore, not surprising that the peasants prefer to work in the early mornings, or if the moon is bright enough, at night. The twilight period is too short to be of significance. Thus, during the fast, both physical efficiency and the length of the working day are reduced, facts which elicit frequent comment in official reports.

For the period 1947–9, the Muslim month of Ramadan coincided with or overlapped the period when rains are normally heavier, that is from May to July. This is also the period when ploughing and field preparation are undertaken. During these three years the Ramadan fast and the consequent loss of physical vitality in many instances retarded the rate of ploughing appreciably, particularly in the 1948–9 season. Reports for all padi areas during this three-year period mentioned the slow progress of ploughing due to the fast. In many areas the peasants, in order to catch the last of the rains, were obliged to plant up fields which had not been brought to the normal standard of tilth and freedom from weeds.

Analogous discordances between agricultural activities and environment have occurred in Sumatra, which was similarly affected by the introduction of Islam. Marsden, the historian of Sumatra, recounts the following: ". . . . . much confusion in regard to the period of sowing is said to have arisen from a very extraordinary cause. Anciently, say the natives, it was regulated by the stars, and particularly by the appearance (heliacal rising) of the *bintang baniak* or pleiades; but after the introduction of the Mahometan religion, they were induced to follow the returns of the *puasa* or great annual fast, and forgot their old rules. The consequence of this was obvious; for the lunar year of the *hejrah* being eleven days short of the sydereal or solar year, the order of the seasons was soon inverted; and it is only astonishing that its inaptness to the purposes of agriculture should not have been immediately discovered"[1].

A similar uncertainty has also been noted on the part of the Muslim Malays of Sarawak. They are obliged to follow the activities of their Dyak neighbours, who in turn are guided mainly by the Pleiades in the fixing of planting dates. Of this method it is said that ". . . . . the Pleiades themselves told them [the Dyaks] when to farm; and according to their position in the heavens, morning and evening, do they cut down the forest, burn, plant and reap. The Malays are obliged to follow their example, or their lunar year would soon render their farming operations unprofitable"[2].

In Malaya padi cultivators, so far as field work is concerned, disregard the lunar calendar and fix their dates of sowing by traditional methods based on the observation of the stars, the sun and the flowering of certain trees. The Pleiades feature prominently in these traditional methods, especially in the northern part of the Peninsula. Of the flowering trees the two which are most commonly employed are the *sentol* (*Sandoricum koetjape*) and the *perah* or *piah* (*Elateriospermum tapos*). Sometimes the seed grain is stored for fixed periods and then planted out. Such methods are useful for two reasons. First, they serve to mitigate the confusion arising from the use of the lunar calendar. Second, they provide more or less fixed points in the agricultural calendar which would otherwise be difficult to determine in a climate of indistinct seasons.

1. W. Marsden, *History of Sumatra* (3rd Edition, London, 1811), p. 71.
2. Spencer St. John, *Life in the Forests of the Far East*, Vol. 1 (London, 1863), p. 214.

In addition to these disharmonies which derive from the interaction of religion and agricultural work, another form of tradition also affects agricultural activities. This is seen operating in the Krian padi lands. The Krian district, on the west coast of Malaya, is one of the country's important padi-growing areas, where crop production depends to a great extent on an efficient irrigation system. The colonizers of this tract of coastal alluvium were mainly Banjarese from South Borneo, with a tradition of swamp cultivation. In the deep marsh environment of their homeland, these Banjarese had devised the technique of floating nurseries[1]. Other ethnic groups, without these traditions and methods of flood farming nurtured in swamp surroundings, are not able to colonize so successfully regions of deep marsh. This type of farming is an integral part of the economic life of the Banjarese, and the descendants of the original colonizers of Krian have retained their traditional methods of cultivation. Swamp methods of cultivation were suitable in the early stages of Krian development, when the water of the area was uncontrolled and consisted mostly of fresh water swamps deeply inundated for the greater part of the year. Then it was only the Banjarese who could deal successfully with such a terrain. Since the introduction of large-scale water control in 1908, however, the environment has been so modified as to render swamp methods of cultivation unnecessary. The cultivators, nevertheless, still cling to their accustomed mode of farming.

The Krian alluvial tract is very flat, and with even normal rainfall water passes off with difficulty, so that very often the fields are submerged under several inches of water by planting time in late June and July. This swamp-like condition is well suited to the traditional technique of the Banjarese. The environmental conditions, together with the farming notions of the cultivators, have induced the habit of regarding the submergence of the whole of the padi-fields as a necessary prelude to nursery preparations preceding the work of field cultivation. In fact, the traditional Banjarese floating nursery, immune from flood, can only be set out after the fields are inundated. With such practices, when dry spells occur leading to the diminution of water in the fields, the cultivators expect water from the irrigation reservoir which serves the area to be used to reproduce the flood conditions to which they are accustomed. In 1930, for example, the Bukit Merah reservoir which supplies water to the entire Krian area, was full to capacity in June. In the following months, rainfall was well below average, resulting in a decrease of water level in the padi-fields, whereupon free discharge was given from the reservoir, the water being used to flood the whole area. This was done in order that the peasants would have water conditions suitable for the setting up of their floating nurseries, and resulted in water shortage by the second week of September when transplanting was about to take place. Thus the retention of a traditional mode of cultivation has here resulted in the wasteful and inefficient use of irrigation water in order to simulate deep swamp conditions to which Banjarese techniques are attuned. The result of this in seasons when rainfall is below normal is that about 50 per cent of the reservoir supply is consumed merely to reproduce conditions which the cultivators regard as a normal prerequisite before the cultivation cycle can begin. This retention of tradition explains the paradox of frequent official allusions to crop damage due to "water shortage" and "drought" in an area of heavy rainfall and with efficient irrigation facilities.

1. These nursery beds are necessary because there is seldom any dry land available, and in any case they escape destruction by floods. This technique is centred around Banjarmasin in South Borneo, where it is known as the Banjar or Banjarese method of padi-farming.

THE DEVELOPMENT OF KUALA LUMPUR DISTRICT

ALTHOUGH KUALA LUMPUR has no long history it merits study not only because it is the federal capital but also because its growth is typical of so many of the inland towns of the Malay Peninsula. Starting as a Chinese tin-mining village ninety-seven years ago, Kuala Lumpur was saved from the fate of most tin-rush towns by its focal position in relation to the Klang River valley in particular, and to the west coast of the Peninsula as a whole. In the pioneering days the Klang River offered the only practicable route to the tin mines upstream. The site of the settlement, at the junction of the Klang with its tributary, the Gombak, can be studied on *HIND 1035, Sheet 3B/15 (Kuala Lumpur), Fourth Edition.*

A contemporary account describes the beginnings of Kuala Lumpur as follows:—

> "In 1857, Raja Jumaat took two towkays to work for tin at Kuala Lumpur. The spot chosen by the coolies was Ampang, and eighty-seven Chinese were sent to work there, but such were the ravages of fevers and tigers that at the end of two months only eighteen were left. Later, Raja Jumaat dispatched a further party of 150 miners in five boats, with provisions. At last the venture was rewarded and in 1859, tin was exported for the first time from Kuala Lumpur and as a very large number of Chinese were then settled at Lukut, a rush was made to the new tinfield and the enterprise soon increased"[1].

Although no early maps exist, it is possible to form a picture of the village from old photographs and contemporary accounts. Sir Frank Swettenham, for example, has published a photograph of 1884 showing a cluster of huts in a muddy compound where now stands the Federal Secretariat[2]. Another Englishman gives a more vivid picture:—

> "We went up the river [Klang] in the steam launch which preceded the *Abdul Samad* to the landing place built for the convenience of the only public work then in hand—namely, the Damansara Road. We rode for some distance on ponies sent ahead by a barge the night before, and then walked by a jungle path, sometimes along slippery *batangs* (ridges), sometimes across them and generally in swampy black soil. The country was quite covered with thick jungle till we reached a red earth scar, and got a view of the village of Kuala Lumpur. Kuala Lumpur consisted of a fairly good loose board house occupied by the Captain China, the most hospitable of men, and his house was surrounded by atap houses, occupied by his coolies. On my late visit to Kuala Lumpur I tried to locate the house, and think it was situated where the two rivers, the Gombak and the Klang, unite"[3].

In 1880 the British moved the administrative capital from Klang to Kuala Lumpur, and within a few years wrought significant changes in the town. In place of cart tracks and river portages there now came wider roads and a twenty-mile track to the coast. It had taken Sir Frank Swettenham three days to reach Kuala Lumpur from Klang by boat; the railway now reduced the journey to less than three hours. By 1896 Kuala Lumpur had its first pipe-water supply and even public gardens, created out of a swampy valley.

Malay peasant agriculture had not been affected by the early Chinese miners, but the British now brought in plantation crops which were adopted by most Malay farmers on a small scale. In 1882, Mr. Thomas Heslop Hill planted Weld's Hill Estate with Liberian coffee, pepper and tea. Coffee at $35 a picul soon displaced pepper at $10, and a decade later there were altogether eleven estates covering an area of 7,000 acres. Meanwhile, the first rubber trees had already been planted at the junction of the present Weld and Treacher Roads. These estates, like the first tin mines, were located well within the town limits, and local names, such as *Koh Bee San* (Coffee Hill) for Weld Road, commemorate this phase of the town's history.

Kuala Lumpur was the commercial and administrative centre for the new industries, but the true function of the town as the commercial headquarters of the Peninsula had still not emerged owing to the lack of communications with the neighbouring states. The town was still overshadowed in importance by Klang, while the extension of the State Railway over the Ginting Peras Pass into Pahang was canvassed as the logical course for opening to Klang the "vast riches" of the interior. Kuala Lumpur was, therefore, still only an entrepot for the trade funnelled through Klang.

With greater security came increased immigration from China, India and Sumatra. As might be expected, the different races tended to group themselves in separate communities. There was also a rough correlation between altitude and social status: the Europeans occupied exclusively the hills on the west bank of the river, while the Chinese persisted in the centre of the town, living in their distinctive two-storeyed shop-houses which have become such a well-known feature of all Malayan

1. Extracted from papers in the possession of Raja Bot bin Raja Jemahat, "History of Selangor", *The Selangor Journal: Jottings Past and Present*, Vol. 1, No. 5 (Kuala Lumpur, 1892), p. 71.
2. Sir Frank Swettenham, *British Malaya* (London, 1906), opp. p. 265.
3. J. Innes, "Selangor, Past and Present", *The Selangor Journal*, Vol. 3, No. 1 (1894), p. 6.

towns. The Malays lived on the swampy land between the Klang and Bunus Rivers, where their stilted, kampong houses are still found today. The Indians took up the remaining living space to the south, contriving always to be near the railway line, which employed large numbers of Indian staff.

The rubber boom of the nineteen-twenties brought fresh prosperity and accelerated development. A comparison of maps of 1908 and 1925 shows the general lines of development. Two roads from the centre of the town crossed the river to the west, branching off into a maze of smaller roads spiralling up the hills. On the east bank, several lengthy arms radiated outwards, terminating at the outer arc formed by Circular Road. The pattern of these straight radial roads reflects the level terrain on the east bank, while their termination at Circular Road marks the edge of the surrounding forests, a relic of which is preserved in the small reserve adjoining the present Golf Course. Drainage of these eastern flats also enabled new satellite roads to be built, linking these main arms.

Fig. 1. The built-up area of Kuala Lumpur in 1895 (Re-drawn from a plan published by *Stanford's Geographical Establishment* and now in the possession of the Surveyor-General of the Federation of Malaya).

Extensive building-up of the roadside lots followed the typical Malayan urban pattern of linear blocks of shop-houses, almost invariably two-storeyed, and open-fronted on the ground-floor for business. Except for the massive John Little's building and the Federal Secretariat, there was nothing to break the monotonous skyline created by the squat, even rooftops. Away from the business centre of the town the Government quarters formed a landscape of semi-detached, red-brick houses,

mainly in the south-eastern part of the town. Not till the beginning of the Pacific War was this uniformity of architecture to be relieved by modern-style office chambers and pleasantly individualistic tenements and bungalows.

In 1909, Kuala Lumpur became the capital of the Federated Malay States, a position it was well suited to fill since through rail communication with North and South Malaya had already been established. Trunk roads over the Main Range also brought the east coast into tribute, and until communication was established with Singapore, Kuala Lumpur was the chief clearing house for the country's trade passing through Port Swettenham.

Kuala Lumpur suffered little war damage apart from the destruction of the museum and the railway workshops. A more fortunate legacy of the war was the new aerodrome. The Japanese summarily disposed of landed interests and by means of compulsory labour enlarged the existing airfield threefold. The war also encouraged an extensive development of squatter settlements within the town, often in close juxtaposition to wealthy residential areas. The more recent insurrections, combined with the threat of resettlement of rural dwellers, has caused another shift to the town so that the population has almost doubled itself since the war. Housing and water-supply have thus become the two biggest problems facing the Municipal Commissioners, who have taken over administrative control of the town since 1948.

The population of Kuala Lumpur to-day is about 300,000. Most of the people live in the eastern half of the old town, between the Gombak and Klang Rivers and Circular Road. Population densities in this region range from 9,000 per sq. mile in the best residential districts to 100,000 in the business centre. In the west, the figure falls to 4,000. This distribution is explained by the fact that town growth in the past has been mainly eastwards towards the tin mines. The largest area added to the Municipality in the recent expansion of 1951, however, was in the west, where the hills have for so long restricted growth.

A probable development in the future is a slight movement of population back to the suburbs, where private and Government sponsored housing estates are making a bid to relieve congestion in the town. Resettlement has resulted in a suburban ring of new villages which will also attract immigrants when the military situation improves. As these satellite settlements, many of which have resulted from military necessity, become integrated with the city, decentralization will allow more scope to a Town Planning Department at present handicapped by congestion and overcrowding.

CHONG SECK-CHIM.

THE PLATEAU AND FALLS OF EAST SARAWAK

The southern part of eastern Sarawak is one of the least known parts of the country, and this is particularly true of the watershed between the Baram and Rajang Rivers. This mountainous region is among the partly explored areas of the world, which is understandable as access is difficult and the sparse population limits itself mainly to the river valleys. The watershed is in the form of a broad tableland, nearly 200 square miles in extent, and exhibiting considerable variety of scenery. To the north rise high, isolated mountain peaks such as Kalulong (5,400 ft.), while the bordering area is rugged hill country. On the west is a deeply dissected fringe of plateau remnants. Numerous rivers drain the area, and where they flow off the plateau cascade down the sheer, cliff-like faces as high falls, some of which appear to be more than 800 ft. high.

As recently as 1949 it was a matter of some controversy whether or not this plateau did exist. In the *Sarawak Gazette* (July, 1949, p. 163) an article entitled "Aerial Reconnaissance of Sarawak" refers to a flight made in this area and states, "Suggestions have previously been made that there is a large high plateau in the interior of the Third, Fourth and Fifth Divisions. The flight revealed no trace of such a plateau". In August the *Gazette* (p. 190) contained an account entitled "The Upland Plateau", where this statement was questioned; while in the September issue (p. 215), further opinions were advanced in an article on "The Baram, Limbang and Trusan Highlands". In April 1951 D. L. Leach and T. Harrisson crossed the watershed between the Baram and Rajang Rivers, their journey being described in an account entitled "The Usun Apau", which appeared in the *Gazettes* of June, July, August and September, 1951. A reconnaissance flight over the Baram—Rajang watershed in August, 1951, when visibility was unusually good, showed clearly an extensive tableland about 3,000 ft. in height. The aircraft flew along the northern edge for some distance, and high waterfalls were observed where tributaries of the Baram River left the tableland. The course of the waters from one particularly fine and striking fall has since been traced down-stream on air photographs, and the river in which it occurs almost certainly identified as the Julan, a tributary of the Baram. This fall is estimated from the air photographs to be over 800 ft. high. The cliff-like edge of the plateau is estimated at various localities to be between 500 ft. and 1,000 ft. in height. The route followed by Leach and Harrisson across the Baram—Rajang watershed skirted the western section of this main plateau, following difficult and rugged valleys cut through igneous rocks. The course taken was up the Dapoi valley from the Tinjar, then across the watershed to the Menawan valley of the Plieran in the Rajang basin. Subsequently the R.A.F. took air photographs of this area, and from this information, combined with that of the expedition, the Land and Survey Department has made the Sarawak Preliminary Sheet, Number 12, on a scale of 2 miles to an inch.

Geologically this region is especially interesting, as it seems likely that the plateau is largely built of volcanic rocks, mainly lava flows and ash material; some pumice has also been found. As far as is known no European has yet been on to the main plateau, but from the air photographs the trees appear to be stunted. The reasons for this are not clear, but it is possibly owing to the rocks being of an acid type, and possibly also to their having weathered to give soils deficient in certain elements important for plant growth.

F. W. ROE.

INDIA AND PAKISTAN: A GENERAL AND REGIONAL GEOGRAPHY

by O. H. K. SPATE.

With a chapter on CEYLON *by* B. H. FARMER. Methuen & Co., Ltd., London, 1954. pp. 828 + xxxvi; 160 maps. Price 65 shillings sterling.

THE PUBLICATION of a new geography of Indo-Pak or Pak-Ind is an important event. Apart from Krebs's study in German, there has been no full-dress and authoritative appraisal of the elements constituting the human ecology of the Indian sub-continent since 1904, when Holdich wrote his blend of history and geography. Much has changed in the fifty years separating that from the new book by Spate. The altered focus shows in simple proportion: Holdich used almost twice as much space for Afghanistan as for all the rest of India, reflecting his interest in external pressures upon and from India; over half of Spate's pages give a detailed analysis of the face of India and about one-fifth to its economics. Spate's first concern, therefore, is to establish the multi-faceted individuality of India, his second to show it engaged in the contemporary struggle about money values and not nearly so soulful and "other-worldly" as the romantics would have us believe.

Probably no one was better fitted than Professor Spate, now at the Australian National University in Canberra, by interest and experience to undertake this encyclopedic work. He modestly states that in his knowledge there are gaps—recognition of which is a major claim to professorial status. He invited Dr. B. H. Farmer to contribute a first-hand account of Ceylon, a sign that the sub-continent has too vast a scope for any one person to handle satisfactorily. A small flow of geographic studies is now coming from professionals within India and Pakistan: Spate has drawn upon them and given generous credit to them.

He has laboured to master the tangle of statistics, changing boundaries and terms which have repeatedly been re-vamped at the hands of over-diligent administrators who so often "started afresh" and never stayed the course long enough to sight their goal. To the old confusions between the British Provinces and the Princely States have been added since 1947 further excisions and migrations, worsened by separatism, by the drift towards linguistic states such as Andhra Desa, and by increasing provincial autonomy. Geographical literature is heavily indebted to Professor Spate for digesting this confused material into a study which must facilitate understanding of a subcontinent whose intricate problems may still defeat Indians and Pakistanis no less than they have the foreigner. His is a definitive contribution such as few Britishers paused to make in the heyday of Imperial India.

The book is heavy in weight, in cost and sometimes in treatment. That it should be the most costly of the expensive Methuen monographs is going to limit it to libraries. Because its price will place it beyond the range of students most needing it, we may regret that severe editing down to a more moderate size was not imposed so as to discipline Spate out of his habit of over-writing. Badly as an author may take it, the advice "cut out a quarter" is often helpful to clarity and in this case might have prevented Spate from being so coyly parenthetic, e.g. on p. 126, "Bazaar or camp English is a wasting asset (as well as an insult to Shakespeare's tongue)", and spared us his Polonius touch, as when writing of the Indian village he says, "Pathetic it still too often is: contented, less and less; which is as it should be" (p. 181). He admits that he has included much which is only tenuously connected with geographical studies.

With over 800 pages at his disposal, he attempts exasperating abbreviations. "Western UP" is not a railway platform but short for "Western United Provinces". "Poptn" is his cryptonym for "population" and "esttd" will stump many readers until they discover it to be Spatese for "estimated", as "geogl." is for "geographical". One sentence on p. 100, beginning "On his view the low female: 1,000 male ratios for humid Bengal....." defeated me until I could tease out that it means, "In his opinion the low ratios of females to males in humid Bengal, etc.".

Being a modern geography, this work is profusely illustrated with maps from Survey of India sources not readily accessible now. Some poor drafting has slipped into the blocks, but will no doubt be rectified in new editions. The half-tone frontispiece is an unfortunate waste of an opportunity.

It is impossible to verify everything in so large a volume, yet testing it for Indo-Pakistan localities known to me directly, I found its presentation and analysis of the landscapes vivid and accurate. Spate's chapter on settlement forms has exceptional merit. On the other hand, interesting and full though his analysis of the agrarian issues may be, it smacks of Houghton Street piety and many readers may ask whether, for example, a passage like this on p. 245 adds anything to a geographer's appraisal of India's agricultural problems, "But seeing what a round of drudgery, monotony and privation the farmer's life generally is, who with any feeling shall blame him for seizing his few socially sanctioned opportunities for bringing into his home some colour and gaiety, a few days of uninhibited projection of his personality, of new clothes and good food?"

Here then is a mine of information and of ideas to illuminate a subcontinent darkened by our ignorance. Professor Spate has done a fine job in presenting so much material despite heavy odds against accuracy in date and perspective: the book must continue for years to be fundamental to the understanding of Southern Asia.

E. H. G. DOBBY.

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ERRATA

Vol. I, October, 1953.

An Outline of the Geography of the Western Region of Nigeria.

p. 17, line 1.....*for* west *read* West.
p. 17, line 2.....*for* north *read* North.
p. 18, line 14.....*for* improvement *read* impoverishment.
p. 21, line 11.....*for* Ijebu, Ode *read* Ijebu-Ode.
p. 22, Fig. 7.....*for* seaward *read* outward.
p. 24, line 3....."Nigerian Soils in Relation to Parent Materials" should be attributed to H. Vine.

The maps in this volume have been drawn by Mr. POON PUAY KEE.

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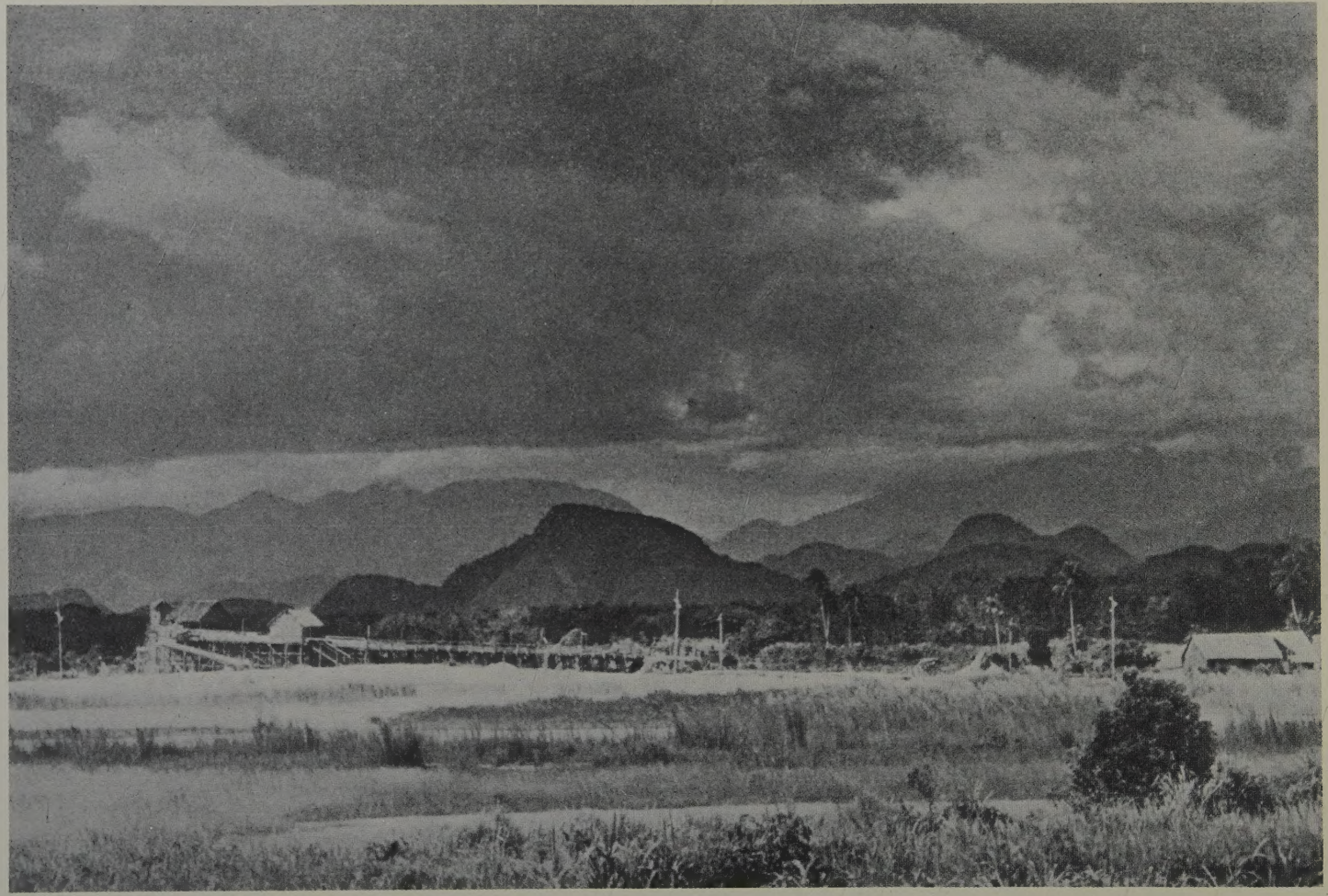

Tin-mining landscape near Senlu, Perak. The scaffolding bears the *palong* of a gravel-pump mine (see text p. 10): the light-coloured ground immediately in front consists of tailings, while the forefront of the picture shows worked-over land with water-filled pits and coarse vegetation. The photograph was taken looking north-east from a point three-quarters of a mile along the road from Senlu to Batu Gajah. The limestone hill in the middle distance is Gunong Lanno, backed by the granite of the Main Range. (Photograph by C. A. Gibson-Hill).